MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1904 *TO NOVEMBER* 1905.

(WITH TWO APPENDICES.)

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXV. NOVEMBER 11, 1904. No. 1

Professor H. H. TURNER, D.Sc., F.R.S., PRESIDENT, in the Chair.

Major C. F. Close, C.M.G., R.E., Brompton Barracks, Chatham; and
Thomas Andrew Common, 63 Eaton Rise, Ealing, W.

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:

Alexander John Samuel Adams, Superintendent and Technical Officer, Post Office Telegraphs London Central, E.C. (proposed by William Ellis);
Captain Arthur ffolliott Garrett, R.E., Craigbeg, Kingussie, Scotland (proposed by H. H. Turner);
P. Groves-Showell, L.C.C. School for Marine Engineering, Poplar, E. (proposed by Sir W. Christie);
George Bruce Halsted, M.A., Ph.D., Professor of Mathematics and Astronomy, Kenyon College, Gambier, Ohio, U.S.A.) (proposed by Professor C. S. Howe);
William T. Litton, Head Master, "Shaftesbury" Training Ship (proposed by Thomas Lewis);
Alfred Noël Neate, Civil Engineer, 34 Prescot Street, New Brighton, Cheshire (proposed by R. C. Johnson);
Alexander Durie Russell, B.Sc., Mathematical Master, High School, Falkirk, Scotland (proposed by P. S. Hardie);

John James Steward, F.R.Met.Soc., Optician, 457 West Strand, W.C. (proposed by William Shackleton);
Lewes H. Tamplin, F.R.Met.Soc., Indo-China Steam Navigation Co., Wuhu, China (proposed by C. H. Brewitt Taylor); and
David Wylie, Teacher of Mathematics, 9 East Road, Lancaster (proposed by Joshua Jukes).

One hundred and sixty-eight presents were announced as having been received since the last meeting, including, amongst others:

R. Buchanan, The Mathematical Theory of Eclipses (presented by the Author); Groningen Astronomical Laboratory, Publications, Nos. 12, 13 (presented by the Laboratory); Annals of Harvard Observatory, vol. xlvi. pt. 2, vol. liii. Nos. 1, 3, vol. lvi. No. 1 (presented by the Observatory); Catalog der Astronomischen Gesellschaft [Leiden and Wien-Ottakring Zones] (presented by the Society); Milan Observatory, Albategnius, Opus Astronomicum, latine versum (presented by the Observatory).

Sixty Charts of the Astrographic Chart, presented by the Royal Observatory, Greenwich, and fifty-nine Charts presented by the French Minister of Public Instruction; twenty-eight Cartes Autographiées (presented by the Toulouse Observatory); seven great enlargements from photographs of the Moon by MM. Loewy and Puiseux (presented by the French Minister of Public Instruction); series of twenty-four transparencies from the late Dr. Roberts's Photographs of Nebulæ (presented by Mrs. Isaac Roberts).

Wire Micrometer by Dallmeyer (presented by Mrs. Irving Noble); Old Ring Dial (presented by Dr. Little).

Magnetic Disturbances, 1882 *to* 1903, *as recorded at the Royal Observatory, Greenwich, and their Association with Sun-spots.* By E. Walter Maunder.

1. *Material Employed.*

Nearly a year ago I prepared a paper on the "Great Magnetic Storms, 1875 to 1903," which was published in the *Monthly Notices*, vol. lxiv. No. 3, p. 205. I confined my examination on that occasion to the instances in which the magnetic movement had amounted to one degree in declination, that being the definition of a "great" storm adopted by Mr. William Ellis, F.R.S., in his paper "On the Relation between Magnetic Disturbance and the Period of Solar Spot Frequency"

(*Monthly Notices*, vol. lx. No. 2, pp. 142–157). But the number of "great" storms recorded in thirty years was only nineteen. I desired, therefore, to extend the examination as soon as possible to a much larger number, and decided to take as the basis of my inquiry all disturbances for which reproductions of the photographic traces were given in the Greenwich volumes. These reproductions have been given regularly since 1882, so that the inquiry commences with that year. The disturbances represented in the plates number about 310 in all, the precise number depending upon the way in which certain long-continued periods of agitation are treated, whether as single disturbances or as series of separate ones, following each other at short intervals.

The first step was to draw up a table of the disturbances to be examined, and I am anxious to state here that the tables upon which all the subsequent work was done were prepared first of all, before the slightest attempt was made to start any inquiry depending upon them. The times of the commencement of the storms, the duration of the storms, the amplitude of the movements of the magnets, and the character of the initial movement all were determined purely from the examination of the plates, before any other investigation was commenced, and in no case have any of these been altered since.

This first table included 310 disturbances; but on its completion it occurred to me that since the selection of disturbances to be represented in the Greenwich plates had not been made with sole reference to the amplitude of the movement it would be worth while to secure an approximation to uniformity by rejecting a few considerably below the rest in range. A range of 20′ in declination was therefore taken as the smallest to be considered, and Table I., containing 276 disturbances, was prepared. The descriptive notes in the Greenwich volumes were also examined for disturbances exceeding 20′ in amount, but not shown in the plates, and a supplementary table was prepared of these, about forty in number. When these are taken into account, although no very broad line of distinction can be drawn between the smallest included and the largest neglected, it is certain that no disturbance of even third-rate importance has been omitted.

A rough classification was next made on the following plan :

Rank of Disturbance.	Greatest Recorded Declination.	Magnetic Movement. Horizontal Force. c.g.s. value × 10^5
Great ...	Greater than 60′	Greater than 300
Very active	Less than 60′ Greater than 40′	Less than 300 Greater than 200
Active ...	Less than 40′ Greater than 30′	Less than 200 Greater than 150
Moderate	Less than 30′ Greater than 20′	Less than 150 Greater than 100

.. —g ~ given to the tenth of an hour.

TABLE I.

Magnetic Disturbances of 20′ and upwards in Declination,
" Greenwich Observations."

Class.	Period of Disturbance. Greenwich Civil Time. From			To			Duration in Hours.	Beginning.	Extreme Am... of Moveme... Dec.	H.F.
	1882.	d	h	1882.	d	h	h		′	
A	Jan.	19	17	Jan.	20	12	19	...	36	·006
M	Feb.	1	13	Feb.	2	12	23	...	35	·005
V		20	6		21	1	19	...	42	·009
G	Apr.	16	23·5	Apr.	17	23	24	S	60+	·030+
3		20	3·6		21	8	28	S	70+	·020+
M	June	15	3·1	June	15	12	9	S	23	·005
r		24	13		25	7	18	...	50	·017
	July	30	23	Aug.	1	11	36	...	33	·009
	Aug.	4	15·9		5	11	19	S	31	·018
	Sept.	12	3·0	Sept.	12	11	8	S	18	·012
	Oct.	2	9·7	Oct.	3	3	17	S	60	·014
		5	18		6	16	22	...	32	·012
	Nov.	11	21	Nov.	15	16	91	...	50	·012
		16	8·3		17	10	26	S	20	·005
		17	10·3		21	4	90	S	110	·050+
		21	16		22	0	8			

Class.	Period of Disturbance. Greenwich Civil Time. From	To	Duration in Hours.	Beginning.	Extreme Amplitude of Movements. Dec.	H.F.	V.F.	No. of Rotation.	Heliographic Coordinates of Centre of Sun's Disc. Longitude.	Latitude.
	d h	d h	h		′				°	°
	1883.	1883.								
M	Feb. 27 16	Mar. 2 22	78	...	25	·006	·002	...	232·6	−7·2
M	Mar. 26 21	28 18	45	...	28	·006	·002	394	234·0	−6·7
V	Apr. 3 9·0	Apr. 4 23	38	S	55	·010	·006	...	135·0	−6·3
M	19 18	20 9	15	...	25	·003	·002	395	279·0	−5·1
A	24 19	26 9	38	...	36	·011	·002	...	212·3	−4·7
M	May 20 19	May 22 8	37	...	28	·009	·002	396	228·6	−1·8
M	June 30 5	July 2 4	47	...	20	·008	·002	397	53·7	+3·0
M	July 8 15·0	11 12	69	S	29	·008	·002	398	302·3	+3·8
M	11 17·4	12 8	15	S	28	·008	·002	...	261·4	+4·1
M	29 23·8	Aug. 2 7	79	S	24	·007	·003	...	19·9	+5·7
M	Aug. 18 16	19 4	12	...	22	·003	·002	399	119·5	+6·9
V	Sept. 16 2·7	Sept. 17 16	37	S	50	·018	·004+	400	103·7	+7·1
A	18 15·6	19 11	19	S	20	·005	·001	...	70·2	+7·1
V	Oct. 5 13	Oct. 6 10	21	...	40	·013	·003	401	207·2	+6·4
A	16 16·1	17 11	19	S	32	·006	·003	...	60·5	+5·7
M	19 19	20 6	11	...	18	·005	·002	...	19·3	+5·4
A	Nov. 1 17	Nov. 3 15	46	...	36	·010	·003	402	208·9	+4·2
M	19 21	20 18	21	...	26	·005	·002	403	329·4	+2·1
A	22 2	24 0	46	...	32	·009	·003	...	300·3	+1·8
	1884.	1884.								
M	Feb. 23 14	Feb. 26 1	59	...	29	·006	·001	406	148·8	−7·1
M	29 19	Mar. 4 1	78	...	28	·007	·002	...	67·0	−7·2
M	Mar. 28 19	29 12	17	...	22	·006	·001	407	58·0	−6·7
M	Apr. 17 15	Apr. 18 12	21	...	22	·005	·002	408	156·2	−5·2
M	24 15	25 12	21	...	29	·006	·002	...	63·8	−4·6
M	June 22 21	June 24 8	35	...	21	·007	·002	411	359·9	+2·2
A	July 2 19·3	July 4 10	39	S	36	·012	·007	...	228·5	+3·3
M	Aug. 8 13	Aug. 10 0	35	...	20	·005	·001	412	102·6	+6·4
M	Sept. 17 13	Sept. 19 11	46	...	25	·007	·002	414	294·0	+7·1
A	Oct. 1 21·9	Oct. 3 9	35	S	30	·012	·003	...	104·4	+6·6
V	Nov. 1 12	Nov. 4 8	68	...	41	·012	·004	415	60·9	+4·1
M	Dec. 22 18	Dec. 23 12	18	...	21	·006	·001	417	105·6	−2·1
	1885.	1885.								
A	Jan. 22 16	Jan. 23 0	8	...	36	·007	·002	418	58·4	−5·5
M	Feb. 5 13·5	Feb. 6 8	19	S	18	·006	·001	419	235·4	−6·5
V	Mar. 15 8	Mar. 16 6	22	...	52	·008	·009	420	97·9	−7·1

[illegible]	[illegible]	[illegible]	Aug.	2	7	23	...	22	·008	
Sept.	4	14	Sept.	5	13	23	...	23	·008	
	15	13		17	1	36	...	30	·006	
	22	13		24	8	43	...	28	·005	
Nov.	10	13	Nov.	12	1	36	...	22	·007	
Dec.	7	14	Dec.	8	11	21	...	23	·005	
	1886.			1886.						
Mar.	18	19	Mar.	20	12	41	...	30	·010	
	30	8·2	Apr.	1	3	43	S	65	·020 +	
Apr.	11	15		15	11	92	...	32	·009	
May	8	19	May	9	11	16	...	43	·012	
June	22	14	June	23	11	21	...	22	·006	
	29	18		30	8	14	...	27	·009	
July	27	18	July	28	12	18	...	45	·013	
Aug.	23	20	Aug.	24	12	16	...	28	·007	
Sept.	9	13	Sept.	14	0	107	...	22	·010	
Oct.	6	17	Oct.	11	8	111	...	40	·008	
Nov.	2	14·7	Nov.	7	0	105	S	26	·007	
	30	12·5		30	21	9	S	32	·005	
	1887.			1887.						
Feb.	12	18	Feb.	15	1	55	...	26	·006	
Apr.	4	14	Apr.	9	2	108	...	24	·006	
Aug.	1	11·1	Aug.	2	7	20	S	24	·007	
	28	20		30	11	39	...	22	·005	
Sept.	25	16	[illegible]							

	Class.	Period of Disturbance. Greenwich Civil Time. From			To			Duration in Hours.	Beginning.	Extreme Amplitude of Movements. Dec.	H.F.	V.F.	No of Rotation.	Heliographic Coordinates of Centre of Sun's Disc. Longitude.	Latitude.
			d	h		d	h	h		′				°	°
			1888			1888.									
10	A	Apr.	11	8	Apr.	14	23	87	...	36	·007	·002	461	36·0	−5·7
11	M	May	7	3	May	10	21	90	...	25	·006	·001	462	55·2	−3·3
12	A		20	12		22	0	36	...	30	·009	·004	463	238·3	−1·8
13	M	June	3	14	June	4	11	21	...	29	·006	·002	...	51·9	−0·1
14	M	Aug.	3	19	Aug.	4	7	12	...	20	·006	·001	466	321·9	+6·1
15	M		16	3		16	23	20	...	22	·006	·001	...	159·0	+6·8
16	M	Oct.	19	19	Oct.	22	0	53	...	29	·006	·001	468	24·2	+5·3
17	A		30	19·7	Nov.	1	12	40	S	35	·007	·001	469	239·8	+4·3
18	M	Nov.	16	19		17	23	28	...	24	·006	·001	...	16·0	+2·4
19	M	Dec.	24	4	Dec.	24	22	18	...	22	·004	·001	471	243·6	−2·4
			1889.			1889.									
20	M	Jan.	20	13	Jan.	21	4	15	...	27	·003	·002	472	243·0	−5·3
21	M	Mar.	6	10	Mar.	6	19	9	...	19	·005	·001	473	12·1	−7·3
22	M		17	20		18	1	5	...	30	·006	·002	474	221·7	−7·1
23	M		28	6		29	1	19	...	28	·008	·001	...	84·3	−6·6
24	A	July	17	4·9	July	17	20	15	S	25	·011	·001	478	57·0	+4·8
25	M	Aug.	13	5	Aug.	13	23	18	...	23	·004	·001	479	60·0	+6·7
26	M	Sept.	8	23	Sept.	11	1	50	...	22	·008	·001	480	66·5	+7·3
27	M		22	13		23	3	14	...	20	·005	·002	481	247·2	+7·0
28	M	Oct.	5	17	Oct.	6	5	12	...	29	·004	·001	...	73·4	+6·4
29	M		18	18		18	23	5	...	22	·005	·001	482	261·4	+5·4
0	M		20	16		21	2	10	...	20	·006	·001	...	236·2	+5·3
1	A	Nov.	1	6	Nov.	2	22	40	...	22	·010	·004	...	83·4	+4·1
2	A		26	15		29	0	57	...	34	·006	·001	483	108·8	+1·2
			1890.			1890.									
3	M	Jan.	3	19	Jan.	4	4	9	...	20	·004	·001	485	326·0	3·5
4	M	Aug.	14	13·9	Aug.	16	11	45	S	18	·006	·001	493	264·2	+6·7
5	M	Sept.	6	12	Sept.	7	10	22	...	18	·003	·001	494	321·4	+7·3
6	M	Oct.	5	13	Oct.	6	5	16	...	24	·005	·001	495	298·1	+6·4
7	M		17	14		19	11	45	...	28	·006	·002	...	139·3	+5·6
8	A	Nov.	7	21	Nov.	8	15	18	...	34	·008	·002	496	218·5	+3·5
9	M		9	13		9	21	8	...	22	·004	·001	...	196·5	+3·3
			1891.			1891.									
0	A	Feb.	11	18	Feb.	15	11	89	...	25	·009	·002	499	35·3	−6·8
1	A	Mar.	2	1·9	Mar.	3	0	22	S	23	·010	·003	500	153·8	−7·3

					[illegible]	[illegible]	[illegible]	...	55	·01[illegible]
V	May	13	8·3	May	17	3	91	S	50	·02[illegible]
M	June	14	8·7	June	14	18	9	S	23	·008
M	Aug.	28	22	Aug.	30	6	32	...	24	·005
A	Sept.	9	10·3	Sept.	12	7	69	S	34	·008
A		28	12		29	12	24	...	34	·009
A	Oct.	23	12	Oct.	27	10	94	...	30	·009
A	Nov.	20	0	Nov.	21	23	47	...	36	·007
A	Dec.	7	11·2	Dec.	7	22	11	S	24	·010
		1892.			1892.					
V	Jan.	4	18·8	Jan.	6	10	39	S	40	·009
G	Feb.	13	5·5	Feb.	14	18	37	S	70+	·029·
M		15	13		16	0	11	...	18	·008
M		20	19·1		21	3	8	S	24	·007
A		27	0		27	22	22	...	31	·008
V		29	21	Mar.	5	5	104	...	40	·014
V	Mar.	6	9·7		9	5	67	S	48	·017+
G		11	22·5		13	5	30	S	75	·026
M		24	20		26	4	32	...	28	·008
V	Apr.	25	15	Apr.	27	7	40	...	58	·018
V	May	1	4	May	2	23	43	...	42	·012
M		16	22·0		17	12	14	S	20	·006
G		18	8·4		19	8	24	S	72	·016

[redacted]

No.	Class.	Period of Disturbance. Greenwich Civil Time. From			To			Duration in Hours.	Beginning.	Extreme Amplitude of Movements. Dec.	H.F.	V.F.	No. of Rotation.	Heliographic Coordinates of Centre of Sun's Disc. Longitude.	Latitude.
			d	h		d	h	h		′				°	°
		1892.			1892.										
57	V	Nov.	4	2·5	Nov.	5	12	34	S	46	·011	·005	523	339·9	+3·8
58	V	Dec.	4	20·3	Dec.	5	5	9	S	36	·016	·006+	524	294·6	+0·1
59	M		5	14		6	1	11	...	27	·006	·001	...	284·7	0·0
		1893.			1893.										
60	M	Jan.	5	13	Jan.	6	4	15	...	28	·008	·002	525	236·8	−3·8
61	M		21	15		22	12	21	...	26	·005	·001	...	25·0	−5·4
62	A	Feb.	4	17	Feb.	6	12	43	...	36	·008	·003	526	199·6	−6·4
63	M	Mar.	14	15	Mar.	15	2	11	...	25	·006	·002	527	60·2	−7·1
64	M		15	15		15	23	8	...	22	·004	·001	...	47·0	−7·1
65	M		25	4·5		25	22	17	S	23	·008	·001	528	280·8	−6·8
66	M		26	7·9		27	6	22	S	26	·007	·004	...	265·9	−6·7
167	A	Apr.	26	16·4	Apr.	27	9	17	S	28	·012	·002	529	212·2	−4·4
168	M	June	9	13·0	June	10	7	18	S	22	·008	·002	531	351·8	+0·6
169	A		18	13		20	11	46	...	20	·009	·002	...	232·7	+1·7
170	V	July	15	22	July	16	9	11	...	46	·012	·004	532	230·4	+4·6
171	M		21	14		22	10	20	...	24	·008	·002	...	155·4	+5·1
172	A	Aug.	6	3·9	Aug.	7	23	43	S	28	·015	·005	533	309·3	+6·3
173	A		18	11		18	23	12	...	30	·014	·008+	...	146·9	+6·9
174	M	Sept.	8	0·9	Sept.	10	0	47	S	20	·006	·002	534	235·0	+7·3
175	M		26	12		27	11	23	...	28	·007	·002	535	351·3	+6·8
176	A		29	13·9	Oct.	1	1	35	S	28	·009	·002	...	310·6	+6·7
177	V	Nov.	1	15	Nov.	2	12	21	...	40	·009	·004	536	234·7	+4·1
78	M		3	12		4	12	24	...	28	·006	·002	...	210·1	+3·9
79	M	Dec.	5	15	Dec.	6	11	20	...	18	·006	·002	537	146·6	+0·1
		1894.			1894.										
80	V	Jan.	3	16	Jan.	4	14	22	...	52	·018	·003	538	124·0	−3·5
1	M		11	19·8		12	10	14	S	20	·012	·001	...	16·5	−4·4
2	A	Feb.	20	20·3	Feb.	22	6	34	S	36	·011	·004	540	209·6	−7·1
3	V		22	22·5		24	10	36	S	50	·015+	·009	...	182·3	−7·1
4	G		25	7·9		26	1	17	S	55	·021	·007+	...	150·5	−7·2
5	V		28	15·3	Mar.	1	3	12	S	50	·019	·005+	...	107·1	−7·2
6	M	Mar.	21	12		23	12	48	...	25	·005	·002	541	192·1	−6·9
7	V		30	17	Apr.	1	0	31	...	56	·018+	·011	...	70·6	−6·5
88	V	Apr.	17	13		18	11	22	...	42	·009	·004	542	195·2	−5·3
89	A	June	9	14	June	11	11	45	...	28	·014	·004	544	213·8	+0·6
90	A	July	2	2	*July*	*3*	*2*	*24*	...	*38*	*·008*	·002	545	275·9	+3·2

riod of Disturbance, reenwich Civil Time. om		To		Duration in Hours.	Beginning.	Extreme Amplitude of Movements. Dec.	H.F.	V.F.	No. of Rotation.	Heli Coord Ce Sun Longitude.
h		d	h	h						°
		1894.								
6·0		21	2	20	S	60	·036	·014	...	35·5
3·0	Aug.	20	18	15	S	65	·022 +	·012 +	547	347·3
13	Sept.	15	8	19	...	36	·016	·010	...	11·5
12		21	6	42	...	25	·008	·004	548	306·1
14·1	Nov.	14	7	17	S	48	·020	·012	550	299·6
		1895.								
13	Feb.	8	22	9	...	23	·006	·002	553	234·0
11		10	11	24	...	33	·009	·003	...	222·0
14		16	10	20	...	26	·007	·002	...	141·3
14	Mar.	9	12	22	...	30	·006	·001	554	224·7
13		15	12	47	...	35	·010	·003	...	159·3
6	Apr.	12	6	24	...	30	·010	·003	555	140·7
7	May	11	1	18	...	32	·010	·002	556	117·1
2·7		20	23	20	S	27	·008	·001	557	228·0

...m.	Period of Disturbance. Greenwich Civil Time. From				To			Duration in Hours.	Beginning.	Extreme Amplitude of Movements. Dec.	H.F.	V.F.	No. of Rotation.	Heliographic Coordinates of Centre of Sun's Disc. Longitude.	Latitude.
		d	h		d	h	h		′				°	°
	1897.			1898.										
A	Jan.	2	12	Jan.	3	3	15	...	38	·005	·004	578	73·5	−3·5
M	Feb.	25	15	Feb.	28	7	64	...	20	·005	·001	580	80·8	−7·2
M	Mar.	10	21	Mar.	11	3	6	...	23	·006	·001	581	266·2	−7·2
M	Apr.	1	18	Apr.	2	10	16	...	26	·010	·003	582	337·8	−6·4
A		20	12		21	3	15	...	30	·007	·004	...	90·3	−5·0
M		23	13		25	12	47	...	28	·008	·002	...	50·1	−4·7
M	May	20	21	May	21	17	20	...	20	·008	·002	583	48·7	−1·8
M	Sept.	4	13	Sept.	5	12	23	...	14	·005	·001	587	77·7	+7·3
M	Oct.	1	20	Oct.	3	11	39	...	22	·005	·001	588	77·5	+6·6
V	Dec.	11	3	Dec.	11	22	19	...	45	·007	·003	591	230·8	−0·7
V		20	13		21	21	32	...	49	·009	·004	...	106·6	−1·9
	1898			1898.										
M	Jan.	16	16	Jan.	19	5	61	...	25	·006	·001	592	109·4	−4·9
M	Feb.	11	6	Feb.	12	3	21	...	28	·007	·002	593	132·6	−6·8
M		12	14		13	3	13	...	21	·004	·001	...	115·0	−6·8
M		14	13		15	11	22	...	20	·007	·001	...	89·2	−6·9
M	Mar.	11	14	Mar.	12	6	16	...	27	·008	·002	594	119·8	−7·2
}		15	0·9		16	8	31	S	75	·018+	·010+	...	73·9	−7·1
M	Apr.	12	16	Apr.	13	10	18	...	20	·006	·002	595	56·2	−5·7
(	Aug.	16	13	Aug.	17	11	22	...	22	·007	·002	600	191·2	+6·8
M	Sept.	2	14	Sept.	3	11	21	...	23	·006	·002	601	326·0	+7·2
}		9	14		10	11	21	...	55	·020+	·010	...	233·6	+7·2
l	Oct.	25	12	Oct.	26	12	24	...	32	·006	001	603	347·8	+4·8
M	Nov.	21	12	Nov.	22	12	24	...	20	·007	001	604	351·8	+1·9
	1899.			1899.										
I	Jan.	28	18·8	Jan.	29	9	14	S	26	·007	·003	606	172·2	−5·9
·	Feb.	11	22	Feb.	13	4	30	...	44	·007	·002	607	346·3	−6·8
M		23	12		24	11	23	...	22	·004	·001	...	193·7	−7·1
L	Mar.	21	22	Mar.	22	12	14	...	32	·008	·002	608	205·6	−6·9
I		23	15		24	4	13	...	29	·008	·002	...	183·0	−6·9
M	Apr.	18	12	Apr.	19	3	15	...	26	·006	·002	609	201·6	−5·2
M	May	1	14	May	2	11	21	...	20	·005	·002	...	28·7	−4·0
M		3	12		4	8	20	...	29	·007	·002	...	3·4	−3·8
M		15	13		16	7	18	...	29	·006	·002	610	204·1	−2·4
V	June	28	12	June	*30*	*11*	*47*	...	*40*	*·010*	·003	612	342·4	+2·8

riod of Disturbance. eenwich Civil Time.					Duration in Hours.	Beginning.	Extreme Amplitude of Movements.			No. of Rotation.	Helio Coordi Cen Sun's
om		To					Dec.	H.F.	V.F.		Longitude.
h		d	h		h		′				°
	1899.										
0	Sept.	27	0		24	...	20	·007	·001	615	239·3
18	Oct.	24	3		9	...	36	·006	·001	616	233·3
	1900.										
18	Jan.	20	0		6	...	28	·006	·001	619	153·7
2	Mar.	14	1		23	...	28	·009	·005	621	184·5
3·2	May	6	0		21	S	29	012	·008	623	204·4
	1901.										
14	Mar.	25	3		13	...	23	·006	·002	635	255·4
11	May	11	0		13	...	32	·007	·001	637	356·4
10	Sept.	11	5		19	...	24	·005	·001	639	170·0
	1902.										

as many as 14. The general result from this part of the investigation was to confirm the conclusion to which a less extended examination on the same lines had led me more than twelve years ago—"though unusually large sun-spots are answered by unusually violent magnetic storms, we cannot as yet proceed further and express the magnitude or character of the magnetic disturbances in terms of the spotted area of the Sun, or of its principal groups at the time of observation." * The fact of a *general* correspondence between the numbers and areas of sun-spots on the one hand and the frequency and intensity of magnetic disturbances on the other was clear. An obvious correspondence between *individual* spots and storms was also manifest when both were of the first rank of magnitude; but a few cases of apparent failure of correspondence were noted when those of the second rank were examined, and these failures became both absolutely and relatively more numerous the smaller the storms or sun-spots included in the inquiry. The two little tables given by the Rev. W. Sidgreaves at the end of his recently published paper, "On the Connexion between Solar Spots and Earth-magnetic Storms," † well represent the general result of this stage of my work. There was "a parallel progression of magnitudes," but there were also some failures of correspondence which seemed to be inconsistent with the conclusion to which the general accord appeared to point.

These failures on the one hand and the very numerous cases on the other, in which several important groups were on the Sun at the time, so that it was impossible to say which should be taken as related to the disturbance, or whether the latter should be ascribed to the joint effect of two or more of them, led me to try if some other class of solar phenomenon showed such a *general* accord with the magnetic disturbances as to warrant the belief that it would give a better particular and special accord than that shown by the spots. For this purpose I prepared Table II. It seemed unfair to give the same weight to a movement lasting over a very few hours as to one lasting several days, so each disturbance in Table I. has in the preparation of Table II. been reckoned according to the number of days or parts of a day during which it was in action. But if the movement attained a different degree of intensity on the different days through which it lasted it has been reckoned accordingly. Thus the "great" storm of 1882 November 17–21 has been reckoned as two days of "great" disturbance, one of "very active" and one of "active"—four days in all. The number of days of disturbance, therefore, is considerably greater than the number of separate outbursts. In Table II. account has also been taken of the "moderate" movements of 20′ and upwards, not shown in the Greenwich plates, but recorded in the notes. These were usually short-lived.

* *Knowledge*, vol. xv. 1892 May, p. 93.
† *Memoirs R.A.S. vol. liv. pp. 95 and 96.*

TABLE II.

Days of Magnetic Disturbance.

Year.	"Great."	"Very Active."	"Active."	"Moderate." In the Plates.	"Moderate." From the Notes.	"Moderate." Total.	Total.
1882	5	6	11	5	6	11	33
3	...	4	9	30	1	31	44
4	...	1	5	18	1	19	25
5	...	2	4	14	...	14	20
6	1	2	10	16	2	18	31
7	...	1	1	15	1	16	18
8	...	1	5	22	1	23	29
9	...	...	3	14	...	14	17
1890	...	...	1	8	...	8	9
1	...	2	11	14	...	14	27
2	6	11	4	21	3	24	45
3	...	2	7	16	8	24	33
4	3	7	3	9	8	17	30
5	...	...	10	6	6	12	22
6	...	4	10	10	3	13	27
7	...	2	2	12	1	13	17
8	2	...	1	12	1	13	16
9	...	2	2	11	...	11	15
1900	...	...	2	1	...	1	3
1	...	...	1	2	...	2	3
2	...	...	2	1	...	1	3
3	1	1	2	8	...	8	12

In the accompanying diagram, fig. 1, the first four lines exhibit the total number of days of disturbance above a certain amount in each year. The first line gives the "great" storms or movements above 60′ in declination; the second, all those above 40′—the "great" and "very active"; the third, those above 30′; the fourth, above 20′, no weighting being applied for the amplitude or intensity of the movement. But in the fifth line each separate class has been weighted so as to give practically the same total value to each of the four classes. The fifth curve, therefore, is practically the mean of the other four.

It will be seen that the years 1882 and 1892 are years of strongly marked maximum for each of the curves except the fourth unweighted one, the number of moderate disturbances being singularly small in 1882, which was very prolific of the greater storms. With this exception the salient features of all the curves are practically the same; the sharply defined maximum

of 1882 is followed by a prolonged minimum, broken only by a revival in 1886. The greater and more sharply defined maximum of 1892 is followed in like manner by a sudden drop, which proceeds in a succession of diminishing waves—1894, 1896, and 1898 being years of slight recovery. It will be seen that no material difference is made in these respects, however we treat the material before us, whether we weight the disturbances according to their

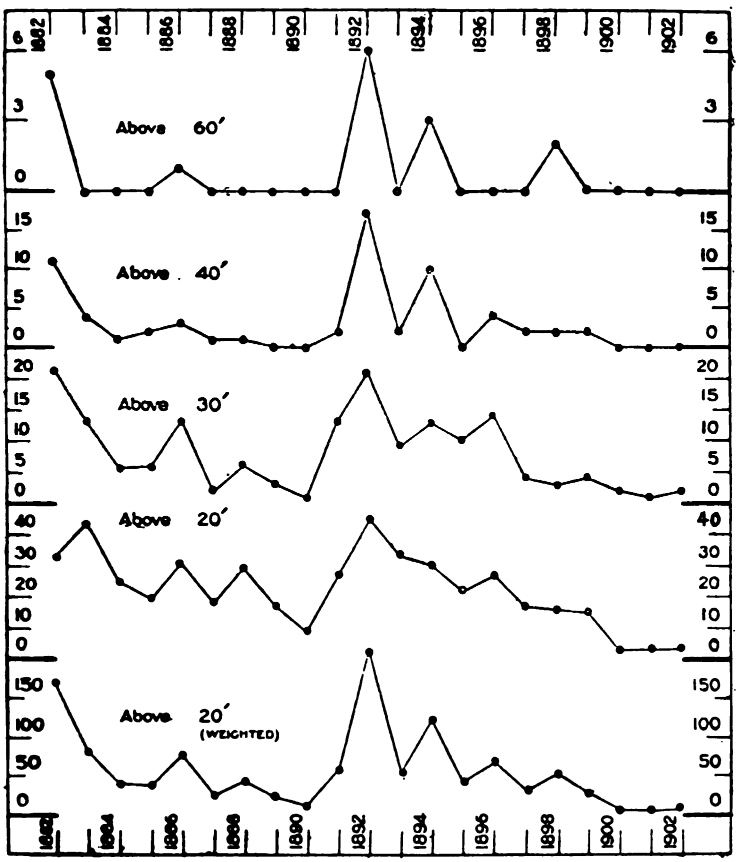


FIG. 1.—Curves of Frequency of Magnetic Disturbances, 1882 to 1903.

importance or whether we take them unweighted; whether we adopt so low a limit as 20′ of movement or whether we confine ourselves to those exceeding twice that amount.

Fig. 2 shows how the weighted curve compares with the various curves of solar activity. The prominence numbers represented are those given by Professor Riccò in vol. xxxii. of the

Memorie della Società degli Spettroscopisti Italiani, and they are shown in two forms. First the northern and southern hemi-

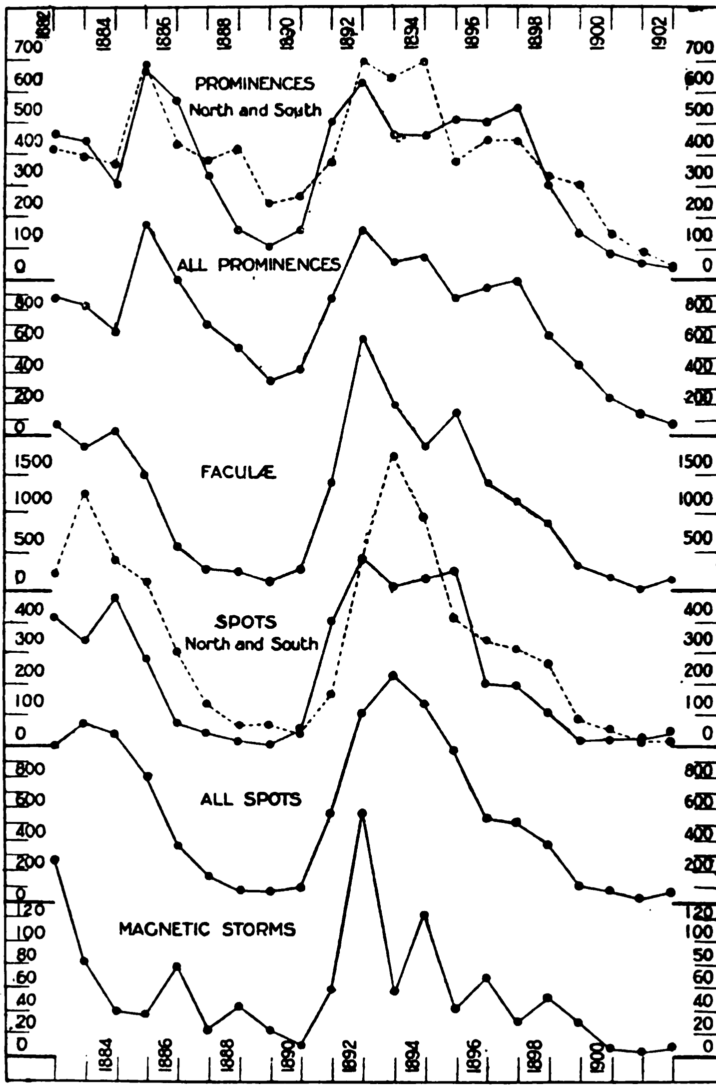


FIG. 2.—Prominences, Faculæ, and Sun-spots compared with Magnetic Disturbances, 1882 to 1903.

spheres are given separately, the northern numbers being joined by a continuous line, the southern by a broken one. Secondly,

the prominences for both hemispheres are given in one curve. Similarly in the fourth line the sun-spot numbers are shown separately for the northern and southern hemispheres, whilst in the fifth line they are combined. The numbers given for the spots and for the faculæ (shown in the third line) are taken from the Greenwich heliographic results.

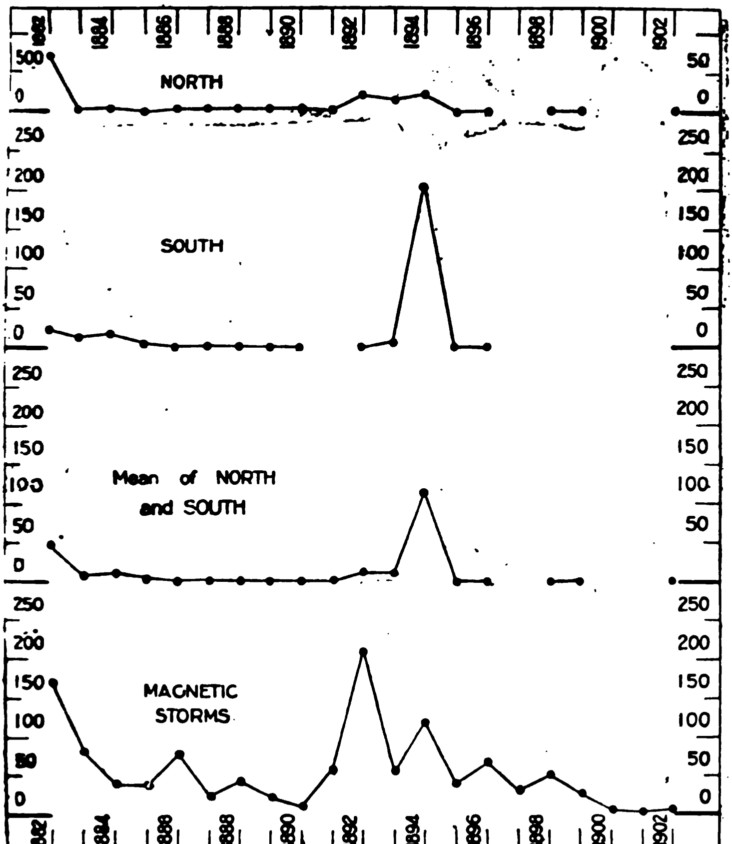


Fig. 3.—Prominences within 20° of the Sun's Pole compared with Magnetic Disturbances, 1882 to 1903.

It will be seen at once that, though the solar cycle shows itself broadly as a whole in the magnetic curve, the chief details of the magnetic curve are not all reproduced in any single one of the other curves. The accord is best with the curve of the faculæ, in which the maximum of 1892 is most strongly accentuated. But 1884 and 1895, both years of great faculous area, were very

quiet years magnetically; and 1886 and 1894, years of magnetic activity, were years of falling off with the faculæ. The inference to be drawn would seem to be that there is no evidence at present of a closer connexion of either prominences or faculæ, rather than sun-spots, with magnetic disturbances sufficient to warrant us in discarding spots, which we can observe continuously, in favour of prominences or faculæ, the observations of which are necessarily defective just where it is most to be desired that they should be complete—that is to say, in the centre of the disc.

Fig. 3 exhibits the prominences of the Sun's polar regions—that is to say, within 20° of the Sun's pole—in comparison with the curve of magnetic disturbance; for the suggestion has been made that it is the polar prominences that have the greatest effect upon terrestrial magnetism. The curves do not seem to lend any support to this suggestion.

3. *Demonstration of the Solar Origin of the Magnetic Disturbances.*

So far no relation of importance had been brought to light; but a suggestion of another method of dealing with the problem arose from a further consideration of my former paper. Of the nineteen "great" magnetic storms sixteen synchronised with the presence of a large group near the centre of the disc. Three did not. But these three are from one point of view even more instructive than the other sixteen, for they synchronised with the *return* in a diminished form of a spot group which had once been large. Of the nineteen storms two were repetitions at the precise interval of a single rotation period of the Sun of two others of the series.

This circumstance suggested the addition to Table I. of the last three columns—viz. a column giving the number of the rotation of the Sun, and two columns giving respectively the longitude and latitude of the centre of the Sun's disc at the commencement of the storm. The same numeration of the rotations, the same prime meridian and rotation period, have been adopted as in the heliographic results given in the annual volumes of the Greenwich Observations.

Fig. 4, Plate 1, represents graphically the information given in columns 3, 5, 10, and 11 of Table I. A separate space in the horizontal direction is assigned to each rotation of the Sun, and each disturbance is represented by a straight line the length of which represents its duration, the line being so placed that its beginning is under the longitude corresponding to that of the centre of the Sun's disc at the time the storm began.

A mere inspection of the diagram brings out a striking and most important relation. The disturbances are not distributed irregularly with regard to the solar meridians, but chiefly affect two or three regions. More noticeable still is the frequency with

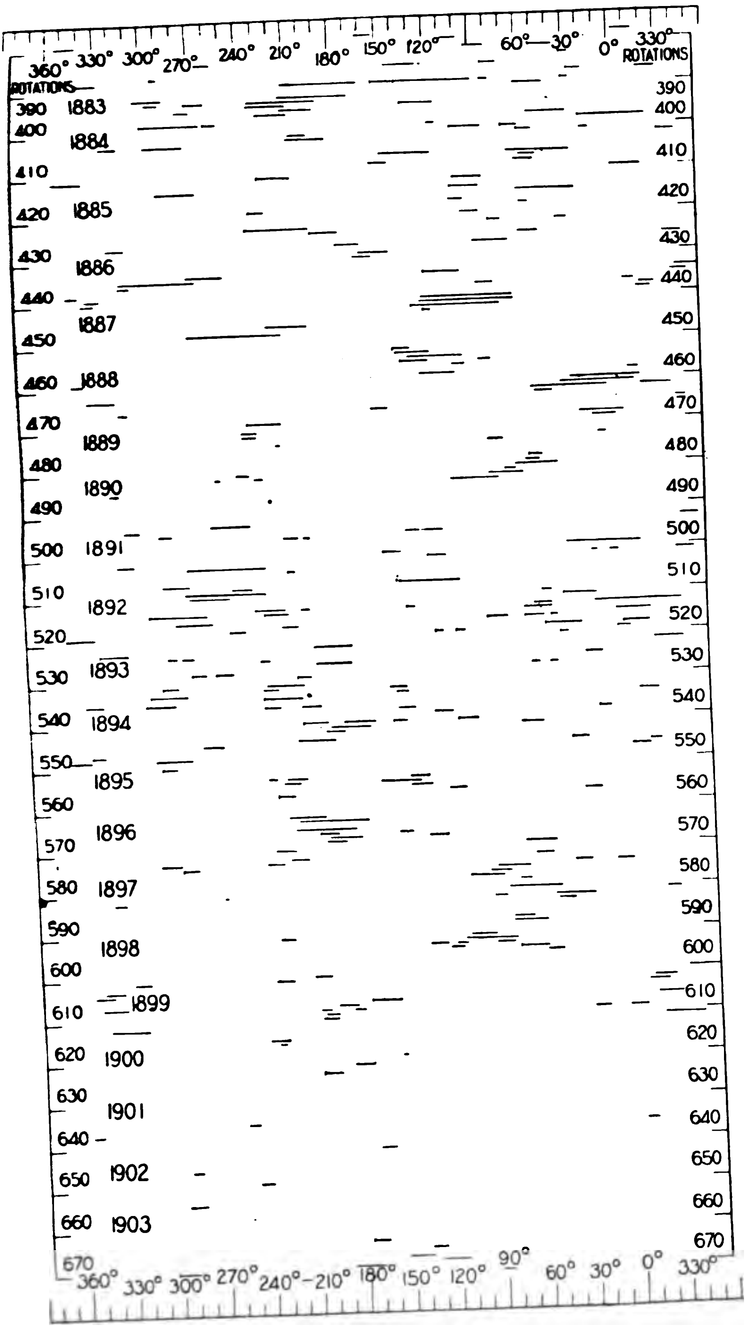


FIG. 4.—Distribution of Magnetic Disturbances, 1882 to 1903, according to the Heliographic Longitude of the Centre of the Sun's Disc at the time of their commencement.

which a disturbance in a given rotation is followed in the next rotation by another when the same meridian of the Sun has returned to the centre of the disc. Table III. shows that there are no fewer than thirty-six distinct sequences of this kind. Nor are these sequences always limited to a single return. The table shows that of the thirty-six sequences, whilst twenty-three extend only to two rotations, eight run through three, four through four, and one through six. It will further be seen that in a large number of cases (printed in heavier type in order to distinguish them) not only did a disturbance recur at the end of a complete rotation of the Sun, but no other disturbance had occurred in the interval.

It will be noted that though, for convenience, Carrington's rotation period has been assumed the remarkable sequences Nos. II., XXI., and XXIII. themselves independently supply a rotation period which does not differ materially from it; indeed, the two last named actually suggested the method of inquiry adopted.

TABLE III.

Magnetic Disturbances recurring in Consecutive Rotations

Reference No. of Sequence.	No. of Rotation.	Reference No. of Disturbance.	Class.	Coordinates of Centre of Sun's Disc.	
				Longitude.	Latitude.
				°	°
I.	519	151	G	359·9	+4·7
	520	154	G	362·8	+6·6
II.	**438**	**72**	**A**	**353·9**	**+2·9**
	439	**73**	**V**	**343·5**	**+5·6**
	440	**74**	**M**	**345·4**	**+7·0**
III.	**603**	**246**	**A**	**347·8**	**+4·8**
	604	**247**	**M**	**351·8**	**+1·9**
IV.	**435**	**69**	**A**	**320·3**	**−5·8**
	436	**70**	**V**	**321·5**	**−3·2**
V.	392	19	M	306·0	−5·7
	393	21	A	298·5	−7·1
VI.	573	217	A	305·2	+6·0
	574	219	M	292·6	+7·2
VII.	**509**	**131**	**A**	**283·4**	**+5·1**
	510	**132**	**A**	**280·8**	**+2·0**
VIII.	**393**	**23**	**M**	**232·6**	**−7·2**
	394	**24**	**M**	**234·0**	**−6·7**

—	513	135	G
	514	141	G
XII.	531	169	A
	532	170	V
XIII.	615	258	M
	616	259	A
XIV.	401	36	V
	402	39	A
XV.	553	197	A
	554	199	A
XVI.	562	205	A
	563	206	A
XVII.	566	208	M
	567	210	V
	568	212	M
XVIII.	608	251	A
	609	253	M
	610	256	M

Reference No. of Sequence.	No. of Rotation.	Reference No. of Disturbance.	Class.	Coordinates of Centre of Sun's Disc.	
				Longitude.	Latitude.
XXII.	532	171	M	155°·4	+5°·1
	533	173	A	146·9	+6·9
XXIII.	440	75	A	124·6	+7·2
	441	76	A	126·0	+6·8
	442	77	M	131·2	+4·1
	443	78	A	123·3	+0·7
XXIV.	399	33	M	119·5	+6·9
	400	34	V	103·7	+7·1
XXV.	591	235	V	106·6	−1·9
	592	236	M	109·4	−4·9
	593	238	M	115·0	−6·8
	594	240	M	119·8	−7·2
XXVI.	455	85	M	88·5	+4·8
	456	86	A	106·2	+1·9
XXVII.	575	222	A	86·9	+6·0
	576	223	A	91·5	+3·4
	577	224	V	105·9	+0·3
XXVIII.	587	232	M	77·7	+7·3
	588	233	M	77·5	+6·6
XXIX.	593	239	M	89·2	−6·9
	594	241	G	73·9	−7·1
	595	242	M	56·2	−5·7
XXX.	400	35	A	70·2	+7·1
	401	37	A	60·5	+5·7
XXXI.	406	43	M	67·0	−7·2
	407	44	M	58·0	−6·7
	408	46	M	63·8	−4·6
XXXII.	478	104	A	57·0	+4·8
	479	105	M	60·0	+6·7
	480	106	M	66·5	+7·3
	481	108	M	73·4	+6·4
	482	111	A	83·4	+4·1
	483	112	A	108·8	+1·2

Reference No. of Sequence.	No. of Rotation.	Reference No. of Disturbance.	Class.	Coordinates of Centre of Sun's Disc. Longitude.	Latitude.
XXXIII.	513	138	A	56°9	−7°2
	514	142	M	63·2	−6·8
XXXIV.	582	230	M	50·1	−4·7
	583	231	M	48·7	−1·8
XXXV.	460	89	M	29·6	−7·1
	461	90	A	36·0	−5·7
	462	91	M	55·0	−3·3
	463	93	M	51·9	−0·1
XXXVI.	468	96	M	24·2	+5·3
	469	98	M	16·0	+2·4

There is no mistaking the conclusion enforced by this table. Covering as it does 295 rotations of the Sun, and including 276 disturbances, it is clear that on the average rather less than one disturbance will fall in each rotation. The probability, therefore, of any disturbance being succeeded by one in the next rotation within 10° of the same solar longitude is about one in forty. Yet forty-seven examples of this are given by Table III. But, as already noted, in several cases the same meridian is active for more than two rotations; there are eight examples in which it runs to three, four in which it runs to four, and one in which it runs to six. The chances against these series being all accidental run into the millions. There is only one conclusion that we can draw from them—namely, that the magnetic disturbances which we experience here are intimately connected with the solar rotation period. Their exciting cause therefore lies in the Sun; there is no possibility of ascribing them to some cause in planetary space, exciting at once the solar photosphere and terrestrial magnetism. Were it so the synodic rotation period of the Sun could not be brought out with such clearness by the times at which these disturbances occur.

This conclusion is quite independent of any comparison with either spots, faculæ, or prominences. If the Sun had never shown one single marking on disc or limb this conclusion would still be inevitable, provided only we knew the rotation period of the Sun; which the spectroscopic method might still have given us. It rests simply upon the times at which successive magnetic disturbances commence. If the Sun's surface were absolutely undiversified we should still know that certain restricted regions of it were capable of exercising this influence upon our Earth, although we had no other indication of any special action there taking place.

But when we examine more closely into the details of Table I. we find that there is a striking correspondence between the characteristics of these magnetic longitudes and those of the longitudes of spot-groups. If the only detail which we could fix concerning sun-spots was their solar longitude, three characteristics would yet make themselves apparent. First, not a few spot-groups would recur, showing themselves in a second rotation; but it would only be a small number that would make a third appearance, and appearances for a fourth or fifth time in succession would be quite rare. Next, different spot-groups would give different rotation periods. This of course is a result of the different rotation periods belonging to different latitudes, the rotation period at the equator being shorter than any other. Third, the frequency of intermittent groups would be remarked; a certain longitude would show a group of spots in one rotation, but would lie fallow during the next, to show a new outbreak in the third, or it might be in the fourth or fifth rotation.

It will be seen that precisely these three peculiarities are shown by the magnetic longitudes. As to the duration of a disturbance it has already been mentioned that we have twenty-three cases of a return in the second rotation, eight in the third, four in the fourth, and one in the sixth, a proportion which corresponds very well with the longevity of spot-groups of the more important and stable kind. The second point, that of the different rotation periods to be derived from these magnetic longitudes, is exceedingly important. In general the rotation period indicated does not differ widely from the mean period adopted in the Greenwich reductions—namely, 25·38 days, corresponding to a daily motion of 14° 11′. But sequences Nos. XXVII., XXXII., and XXXV. indicate a much more rapid rotation, and Nos. VI., X., XXIV., and XXIX. a much slower rotation. In the mean the former correspond to a daily motion of 14° 32′, 5′ larger than the mean motion found by Carrington for the equator, whilst the latter give a mean motion of 13° 39′, corresponding to the mean of those found by Carrington for latitude 30°. The rotation periods therefore given us by the magnetic disturbances not only agree in the mean with the rotation periods given by sun-spots, but the limits within which they vary are the same. We are therefore not only precluded from looking for the exciting cause in regions outside the Sun altogether, but we are restricted to his surface and to that portion of it rotating within these limits of velocity; in other words, to the principal sun-spot zones. If our rotation period of the Sun had been derived from its polar regions, none of these sequences, shown in Table III., would have held good.

The third feature, that of intermittent action, shown by spot-groups is a very striking one. Two instances, taken quite at random, one in the northern and one in the southern hemisphere—may suffice.

TABLE IV.

Example of an Intermittent Northern Spot-Group.

Rotation.	No. of Group.	Mean Long.	Mean Lat.
534	3191	50°·44	+12°·41
535	3232	53·13	+11·77
536	3272	56·27	+10·63
	Interval of 5 rotations.		
541	3460	53·44	+ 9·79
542	3492	54·85	+11·90
	Interval of 3 rotations.		
545	3629	56·44	+ 7·52
	Interval of 4 rotations.		
549	3777	51·37	+ 7·40
550	3824	52·67	+10·93

TABLE VI.

Magnetic Disturbances recurring after two Rotations.

Reference No. of Sequence.	No. of Rotation.	Reference No. of Disturbance.	Class.	Coordinates of Centre of Sun's Disc. Longitude.	Latitude.
XXXVII.	533	172	A	309°·3	+6°·3
	535	176	A	310·6	+6·7
XXXVIII.	548	194	M	306·1	+7·1
	550	195	V	299·6	+2·8
XXXIX.	393	22	V	273·4	−7·2
	395	26	M	279·0	−5·1
XL.	469	97	A	239·8	+4·3
	471	99*	M	243·6	−2·4
XLI.	532	170*	V	230·4	+4·6
	534	174	M	235·0	+7·3
	536	177	V	234·7	+4·1
XLII.	394	24*	M	234·0	−6·7
	396	28	M	228·6	−1·8
XLIII.	563	206*	A	215·2	+3·3
	565	207	A	217·7	−3·5
XLIV.	406	42	M	148·8	−7·1
	408	45	M	156·2	−5·2
XLV.	553	198	M	141·3	−6·9
	555	201	A	140·7	−5·8
XLVI.	379	3	V	107·8	−7·1
	381	4	G	93·0	−5·4
XLVII.	412	49	M	102·6	+6·4
	414	51	A	104·4	+6·6

* These disturbances occur also in Table III.

Reference No. of Sequence.	No. of Rotation.	Reference No. of Disturbance.	Class.	Coordinates of Centre of Sun's Disc. Longitude.	Latitude.
XLVIII.	578	225	A	78°·5	−3°·5
	580	226	M	80·8	−7·2
	582	229	A	90·3	−5·0
XLIX.	514	142*	M	63·2	−6·8
	516	146	G	63·3	−2·0
L.	381	5	G	51·2	−5·0
	383	6	M	30·9	+1·3
LI.	516	147	M	45·9	−1·9
	518	150	V	49·8	+4·3
	520	155	M	39·9	+7·3
LII.	387	11	G	26·3	+6·6
	389	17	A	30·4	+1·3

Tables III. and VI., which bring out so strikingly the tendency of magnetic disturbances to recur when definite meridians of the Sun are on the centre of the disc, include between them 121* disturbances out of the 276 of Table I.: that is to say, very nearly half. If longer intervals of time than two rotations be taken a considerably greater number of sequences would be shown, and not a few of those given in Tables III. and VI. would be found to be continued at irregular intervals over considerable lengths of time. Rather more than three-fourths of the entire number of disturbances of Table I. appear to fall naturally into these more extended and irregular sequences. These are of course much less certain in their character than are those cases in which two successive disturbances occur when the same solar longitude has returned to the centre of the disc after the interval of a single rotation, and on the probabilities of the case some at least must be merely accidental. But that some at least of these more extended and irregular sequences are real, and not due to mere chance grouping, may, I think, be fairly inferred from such an instance as that presented by the two sequences of Table VII. In the period from 1895 February 9 to 1896 March 27, a period of fifty-nine weeks, sixteen disturbances were observed. Of these sixteen no fewer than nine synchronised with the return of one solar meridian to the centre of the disc, and three with the return of another. It seems contrary to all probability that so striking a relation as this should be merely one of accident throughout.

* Table III. contains ninety-one disturbances; Table VI., thirty-five; but five are common to the two tables.

TABLE VII.

Example of two Magnetic Meridians of long-continued Activity.

No. of Rotation.	Reference No. of Disturbance.	Class.	Coordinates of Centre of Sun's Disc. Longitude.	Latitude.
553	197	A	222°·0	−6°·7
554	199	A	224·7	−7·3
Interval of 3 rotations.				
557	203	M	228·0	−0·9
Interval of 5 rotations.				
562	205	A	228·8	+6·0
563	206	A	215·2	+3·3
Interval of 2 rotations.				
565	207	A	217·7	−3·5
566	208	M	202·4	−6·1
567	210	V	195·4	−7·2
568	212	M	197·2	−6·7
553	198	M	141·3	−6·9
Interval of 2 rotations.				
555	201	A	140·7	−5·8
Interval of 11 rotations.				
566	209	A	149·7	−6·4

When disturbances at a still greater distance apart are compared a further relationship appears to suggest itself, for there seems to be a marked tendency for a magnetic meridian to be active at the interval of a year, or, more strictly speaking, of thirteen or fourteen rotations. In the ordinary way this would be a very difficult relation to establish; it would be quite impossible to do so at the solar maximum when disturbances are numerous. But it will be seen from Table I. that in the year 1900 only three disturbances were recorded, and that each one of these three agreed closely in longitude with a disturbance thirteen rotations earlier. Table I. supplies in all some twenty-six examples beside the three just mentioned in which a disturbance is followed at the end of thirteen or fourteen rotations by another within 10° of the same longitude. No doubt many of these are merely chance correspondences, but the number found is quite twice as large as would be expected if all were such, and we may therefore fairly conclude that there were at least fourteen or fifteen instances of the same area being magnetically active at the beginning and end of a period of twelve months. Such an area, in order to be in evidence in this way, must of course have a rotation period

Table VIII.

Magnetic Storm.						Assoc		
Ref. No. of Storm.	Ref. No. in Table I.	Class.	No. of Rotation.	Coordinates of Centre of Sun. Longitude.	Coordinates of Centre of Sun. Latitude.	No. of Spot Group.	Mean Area.	I I
	3	V	379	107°·8	−7°·1			
4	4	G	381	93·0	−5·4	726	833	
5	5	G	381	51·2	−5·0	729	1744	
	6	M	383	30·9	+1·3			
8	68	G	434	122·5	−6·5	1860	487	1
	75	A	440	124·6	+7·2			
	76	A	441	126·0	+6·3			
	77	M	442	131·2	+4·1			
	78	A	443	123·3	+0·7			
9	135	G	513	238·2	−6·8	2421	2402	2
10	141	G	514	233·2	−7·2	2440	386	2
	160	M	525	236·8	−3·8			
	169	A	531	232·7	+1·7			
	170	V	532	230·4	+4·6			
	174	M	534	235·0	+7·3			
	177	V	536	234·7	+4·1			

Magnetic Storm.						Associated Spot-Group.				
Ref. No. of Storm.	Ref. No. in Table I.	Class.	No. of Rotation.	Coordinates of Centre of Sun. Longitude.	Latitude.	No. of Spot Group.	Mean Area.	Mean Coordinate of Spot Group. Longitude.	Latitude.	Distance South of Centre.
				°	°			°	°	
	239	M	593	89·2	−6·9					
17	241	G	594	73·9	−7·1	4702	970	119·5	−13·2	6·0
	242	M	595	56·2	−5·7					
	234	V	591	230·8	−0·7					
18	245	G	601	233·6	+7·2	4781	1556	239·0	−12·1	19·3
	258	M	615	239·3	+6·9					
	259	A	616	233·3	+5·0					
	266	M	646	290·7	−4·7					
	268	A	654	294·9	+7·0					
19	274	G	670	304·1	+4·4	5098	470	298·1	−18·8	23·2

The last column in the preceding table gives for the spot-group supposed to be connected with the storm the least distance of its centre from the centre of the Sun's disc—its distance, that is, when in transit across the central meridian. In every case the spot-group was south of the centre of the Sun.

It will be seen, by reference to the detailed history of the spot-groups given in my former paper, that the sequences, if they indicate a continued action from the same area, prove that such areas can be magnetically active both before the spot has formed and after it has disappeared. A very clear case of the magnetic action continuing after the disappearance of the spot occurred during the minimum year 1889. On July 17 an "active" disturbance began with the characteristic sharp movement. It was followed in the next rotation by a "moderate" one at a slightly increased longitude; and so on, rotation after rotation, for six successive rotations. There was no possibility of confusing any of the members of this sequence—No. XXXII. of Table III.—with those of any other; they followed, rotation after rotation, without any intermission, and the only other disturbances—three in number—which took place during the five months that the sequence lasted occurred just half a rotation distant from them in time—in other words, when this side of the Sun was turned directly away from us.

The state of the Sun at the time when the first of these disturbances occurred was this: The largest group of the year —Group No. 2090, described in my "Note on the Sun-spots of 1889"*—was crossing the disc for the second time as Group No. 2092, and a new group of intermittent character, which in the following rotation became the third group of the year in

* *Monthly Notices*, vol. l. p. 369.

... ...ed to return for three rota
pearance of this last feeble remnant of the

The following conclusions appear to res
before us :

First. The origin of our magnetic dis
Sun ; not in any body or bodies affecting
from the manner in which those disturbanc
rotation period ; not the actual sidereal pe
period ; the period as it appears to us.

Second. The areas of the Sun giving
disturbances are definite and restricted area
with which certain longitudes are indicated
are not due to a general action or influer
whole solar surface.

Third. The region of the Sun, wherein
active areas are situated, rotates with the
spot-bearing zones, viz. latitudes 0° to 30°.

Fourth. As shown in my former paper th
storms are clearly connected with great sun-
of synchronism between individual storms a
being too numerous and precise to be acciden

Fifth. These active areas on the Sun car
magnetically active before the visible formati
they evidently can continue to be magnetica
spot-group has disappeared. It would appe
formation is an important phase of the acti
but that other phases of that activity can
survive such spot-formation, just as facula
survive spots.

Sixth. The influence proceeding from the
character, does not act ...

of energy radiating in all directions from the Sun as a centre, if such storms bore no relation to each other. It is not possible so to account for such an effect when it is followed by others exactly at the interval of one or more synodic rotation-periods of the Sun. Such a relation can only be explained by supposing that the earth has encountered, time after time, a definite stream, a stream which, continually supplied from one and the same area of the Sun's surface, appears to us, at our distance, to be rotating with the same speed as the area from which it rises.

Seventh. The average diameter of such streams may be roughly estimated from noting the time which an average storm lasts. Those in Table I. give an average duration of thirty hours, in which time the longitude of the centre of the Sun's disc appears to us to change by $16^{\circ}\cdot5$. This would imply an average diameter for these stream-lines of 20° supposing them to be circular in section. An average stream-line will therefore occupy about $\frac{1}{130}$th part of the entire sphere, instead of the whole of it, as the magnetic wave from the Sun would do if it spread out equally in all directions.

Eighth. It follows, therefore, that, if sun-spots be the real seat of the energy giving rise to our earth-magnetic disturbances, the majority of them must fail to affect us. A similar conclusion results from comparing the numbers of magnetic disturbances and of spot-groups; for whilst Table I. contains only 276 entries, the Greenwich sun-spot record for the same period gives more than 4,500 spot-groups, of which more than 600 might be classed as considerable, the least important having been visible for at least eight consecutive days, and having a mean area of 200 millionths of the Sun's visible hemisphere.

Ninth. It follows from the fifth and eighth conclusions that, though sun-spots and magnetic disturbances are intimately connected, large sun-spots will often be observed when no disturbances are experienced, whilst sometimes disturbances will be experienced when no spots with which they can be associated are visible. The familiar and oft-repeated phenomenon of "intermittent spot-activity" suggests that often, if not always, the spot should be regarded in these cases as dormant rather than as having ceased to exist, the spot-forming forces being possibly still at work below the photosphere.

Tenth. The last column of Table VIII. suggests that stream-lines proceeding from the Sun and giving rise to the magnetic disturbances are not necessarily always truly radial in direction.

In the valuable paper by the Rev. Walter Sidgreaves already referred to, "On the Connection between Solar Spots and Earth Magnetic Storms," an immense amount of material has been discussed, and the results, as the author expressly remarks, afford proof of a real connection between spots and magnetic storms. He was, however, held back from the natural conclusion that the cause of these storms resided in the Sun by two considerations, the one observational, the other theoretical. The

observational difficulty was the fact to which I called special attention more than twelve years ago *—that great spots have been seen when there have been no storms, and storms experienced when there have been few or no spots. That difficulty is now removed, since it is seen that spots ought not always to be accompanied by storms on the one hand, whilst the storms themselves show their solar origin apart from any question of individual spots on the other.

On the theoretical difficulty Father Sidgreaves wrote: "The question, 'Is the source of energy affecting our magnets on the Sun?' is a question admittedly settled in the negative theoretically," and he quoted the well known presidential address of Lord Kelvin to the Royal Society in 1892. But Father Sidgreaves strangely passed over without notice a most significant qualification in Lord Kelvin's conclusion. Lord Kelvin wrote: "Thus in the eight hours of a not very severe storm as much work must have been done by the Sun *in sending magnetic waves out in all directions through space* as he actually does in four months of his regular heat and light." I have italicised certain words because these form the basis of Lord Kelvin's computation, and it is to these that his conclusion applies. It is only as we assume this condition, so explicitly stated by Lord Kelvin, that we can reach his conclusion. And that condition does not hold good. As I have shown in this paper the magnetic disturbances themselves supply absolutely conclusive evidence that they are not due to magnetic waves spreading out from the Sun equally in all directions through space. They are due to action along definite restricted lines.

There is no necessity for me to expound at length the magnitude of the change thus made in our way of regarding the solar action. The difference between the universal action of a "polarised magnetic sphere" and the action of restricted stream-lines is fundamental.

Stream-lines proceeding from the Sun have been actually photographed. In 1898, after the eclipse of that year, my wife and I wrote of the photographs taken by her: "The chief features shown by these long-exposure photographs are four long rays. . . . The lengths given for the rays are, of course, their apparent lengths; their real lengths are probably considerably greater, for we do not know in what plane they lie, nor how far their apparent lengths have been diminished by fore-shortening; the values given above" (13·9 lunar radii in the extreme case) "therefore are a minimum. The rays in appearance are straight, narrow, and rod-like up to the limits given." †

This was the first occasion upon which these rod-like rays were clearly photographed. The present paper, by an entirely different class of evidence, has shown that stream-lines analogous in form are being driven off from the Sun. The same photo-

* *Knowledge*, vol. xv. May 1892, p. 93. † *The Indian Eclipse*, p. 117.

graphs showed also for the first time the real significance of the synclinal structures of Mr. Ranyard. We wrote: "But their bases" (*i.e.* of the long rays) "are of an altogether different form. Each one rises from one of those 'synclinal structures' to which Mr. Ranyard called attention in his great eclipse volume (*Memoirs R. A. S.* vol. xli.) Only four of these structures were seen in this eclipse, and in each case we now see from these photographs that they terminate in one of these rod-like rays. The bending towards each other of these synclinal curves is therefore, not apparent only, as being due to some effect of perspective, nor accidental, but is of the very nature of their structure." The building up of these synclinal structures was shown in the same eclipse on photographs taken by Mr. C. Thwaites with the fine photo-visual telescope lent to him by Mr. G. J. Newbegin. Concerning these we wrote: "These show us that over the principal prominences and at some little distance an arch of coronal matter is formed. This is succeeded by a larger arch outside, and so on for a succession, the outer arches being less definite and complete than the inner ones. Outside all we find the curves defining the boundaries of the synclinal group. . . . From the apex of the synclinal structure we find the coronal matter driven outwards in a straight line, which probably indicates an immense velocity. It must be noted that this eruptive action is not always radial. One of the long rays in 1898 was tangential and another was oblique." *

As to the physical cause of these streams and the condition of the matter composing them it does not lie within my province to offer any suggestion. The one supplied by Professor Svante Arrhenius, published in the appendix to the *Monthly Notices*, vol. lxiv. No. 8, that they consist of minute droplets formed by condensation in the Sun's atmosphere, negatively charged and driven away by the pressure of radiation, seems entirely consistent with the appearance of the coronal photographs, and with the conditions indicated by the magnetic storms.

That, therefore, which Lord Kelvin spoke of twelve years ago as "the fifty years' outstanding difficulty" is now rendered clear. Our magnetic disturbances have their origin in the Sun. The solar action which gives rise to them does not act equally in all directions, but along narrow, well defined streams, not necessarily truly radial. These streams rise from active areas of limited extent. These active areas are not only the source of our magnetic disturbances but are also the seats of the formation of sun-spots, and their activity is ordinarily most easily and continuously manifested to us by the presence of sun-spots, and by the changes which such spots undergo. But these areas can be magnetically active both before a spot has formed and after it has disappeared. Though, therefore, sun-spots and magnetic

* *The Indian Eclipse*, p. 121.

disturbances have an ultimate connection the latter can occur when no spots are visible. On the other hand, since the solar action is restricted in its direction, many great spots may be visible to us without any effect being produced on the Earth's magnetism. But that the disturbances have an intimate connection with the spots is clear from the fact that they occur at intervals corresponding to the rotation period of the Sun as determined by sun-spots, and to the special rotation periods of those zones of the Sun where sun-spots most congregate, whilst they exhibit in the times of their returns some of the chief sun-spot characteristics, and in not a few instances individual storms have been clearly associated with individual groups of sun-spots.

Postscript.—It will be noted that I have rigidly confined myself to the disturbances which I scheduled in Table I. at the beginning of my inquiry. In not a few cases disturbances of slightly smaller amplitude tend to complete the less regular sequences, but I thought it better to omit all references to them rather than to enlarge indefinitely the scope of the paper.

86 *Tyrwhitt Road, St. John's, Brockley, S.E.:*
1904 *November* 4.

A Discussion of the Long-Period Terms in the Moon's Longitude. By P. H. Cowell.

The following empirical corrections satisfy the observations of the Moon's longitude from 1750 to 1901 very closely, and, as far as I know, they are not inconsistent with the observations previous to 1750. The time is measured in units of 40×400 lunar days, or forty-five years nearly from the middle of my sixty-seventh period of analysis, or the year 1826·1.

The second line of the formula, which is supposed to be applied to the Hansen-Newcomb system at present used by the *Nautical Almanac*, is merely a removal of Newcomb's empirical term:

$$\begin{aligned} -4''\!\cdot\!3 + 15''\!\cdot\!0 \cos 45°t &- 9''\!\cdot\!7 \sin 45°t \\ -12\cdot 2 \cos 60°t &+ 9\cdot 5 \sin 60°t \\ -\ 2\cdot 3 \cos 246°t &+ 0\cdot 5 \sin 246°t \\ +\ 0\cdot 2 \cos 390°t &- 0\cdot 7 \sin 390°t \end{aligned}$$

The period of the term 45°*t* is about 363 years; that of Newcomb's term, 273 years; the periods of the two shorter terms are 66 and 42 years.

The above formula has been formed on the assumption that

one, and only one, empirical term of very long period is to be introduced, and also that the secular acceleration is not to be altered. With these limitations I believe the solution is unique—that is to say, it only admits of variations proportional to the errors of observation, and no totally different solution can be found. The assumption of two or more long-period terms opens possibilities too vast to be discussed. As to the secular acceleration, the terms

$$+15''\cdot 0 \cos 45^\circ t - 9''\cdot 7 \sin 45^\circ t$$

in the above formula may be replaced by

$$\begin{aligned} &+9''\cdot 8 \cos 50^\circ t + 5''\cdot 2 - 4''\cdot 4 T^2 \\ &-7''\cdot 2 \sin 50^\circ t - 3''\cdot 0 T \end{aligned}$$

where T is measured in centuries.

The argument $50^\circ t$ has a period of 327 years, and, as the eclipses discussed by Professor Newcomb and Mr. Nevill (*Monthly Notices*, vol. xxxix. p. 73) point to a negative correction to the secular acceleration of about $2''$, my conclusion is that if a single long-period empirical term alone exists its period should be about 350 years, and not 273 years, as Professor Newcomb has taken it.

Table I. gives the separate terms of the empirical formula at the beginning of this paper, tabulated for $t = -4, -3, -2$, *i.e.* for 180, 135, 90 years before 1826, and also for the middle of every fourth of my periods of analysis of 400 lunar days each from -1 to $+135$.

It will be seen that from 1650 to 1750 the numerical value of my formula is less than $5''$. If, therefore, Professor Newcomb's empirical term satisfies the observations for these hundred years, so also does mine.

TABLE I.

Numerical Values of Empirical Terms. Unit $0''\cdot 1$.

	-43 $+150 \cos 45^\circ t$ $-97 \sin 45^\circ t$	$-122 \cos 60^\circ t$ $+95 \sin 60^\circ t$	Sum of Two Preceding Terms.	$-23 \cos 246^\circ t$ $+5 \sin 246^\circ t$	$+2 \cos 390^\circ t$ $-7 \sin 390^\circ t$	Sum of all Four Terms
$t=-4$	−193	+143	−50	...	...	...
$t=-3$	−80	+122	+42	...	...	...
$t=-2$	+54	−21	+33	...	...	...
Period						
−1	+87	−68	+19	−16	−5	−2
+3	+95	−81	+14	−22	−7	−15
7	+104	−95	+9	−24	−6	−21
11	+111	−107	+4	−21	−3	−20
15	+118	−118	0	−15	+2	−13
19	+123	−128	−5	−5	+6	−4

Period	-43 $+150 \cos 45^\circ t$ $-97 \sin 45^\circ t$	$-122 \cos 60^\circ t$ $+95 \sin 60^\circ t$	Sum of Two Preceding Terms.	$-23 \cos 246^\circ t$ $+5 \sin 246^\circ t$	$+2 \cos 390^\circ t$ $-7 \sin 390^\circ t$	Sum of all Four Terms
23	+128	−137	−9	+5	+8	+4
27	+132	−143	−11	+14	+6	+9
31	+134	−149	−15	+20	+1	+6
35	+135	−153	−18	+23	−4	+1
39	+136	−155	−19	+22	−7	−4
43	+135	−155	−20	+16	−7	−11
47	+133	−154	−21	+9	−4	−16
51	+130	−151	−21	−2	+1	−22
55	+126	−145	−19	−11	+5	−25
59	+120	−139	−19	−19	+7	−31
63	+115	−131	−16	−23	+6	−33
67	+107	−122	−15	−23	+2	−36
71	+99	−111	−12	−19	−2	−33
75	+90	−99	−9	−11	−7	−27
79	+80	−87	−7	−1	−7	−15
83	+70	−73	−3	+8	−5	0
87	+59	−58	+1	+17	0	+18
91	+47	−43	+4	+22	+5	+31
95	+34	−27	+7	+24	+7	+38
99	+21	−11	+10	+21	+6	+37
103	+8	+5	+13	+14	+3	+30
107	−6	+21	+15	+4	−2	+17
111	−20	+37	+17	−5	−6	+6
115	−33	+52	+19	−15	−8	−4
119	−48	+68	+20	−21	−6	−7
123	−61	+81	+20	−23	−1	−4
127	−76	+95	+19	−22	+4	+1
131	−89	+107	+18	−16	+7	+9
135	−103	+118	+15	−8	+7	+14

Table II. gives, for each period from 1 to 89, (i) the mean error, tabular *minus* observed, of the Moon's longitude, the tabular places being those used by Airy with the corrections given in *Monthly Notices*, vol. lxiv. pp. 571–573; (ii) a long-period correction, representing the excess of the mean longitude and 273-year term now used in the *Nautical Almanac* over the mean longitude used by Airy; (iii) the sum of the two preceding columns.

The long-period terms of the Hansen-Newcomb tables are

$$+15''\!\cdot\!34 \sin (A + 30^\circ\ 12')$$

as given by Hansen, and

$$-15''\cdot5 \cos A,$$

Newcomb's empirical term, where A is an argument whose numerical value for the middle of my *p*th period is (see *Monthly Notices*, vol. lxiv. p. 421)

$$183^\circ\cdot8946 + 1^\circ\cdot4953\ (p-44).$$

To get the mean longitude of the Hansen-Newcomb system now used in the *Nautical Almanac* I have formed $g+\omega-\Theta$ from Hansen's *Tables de la Lune*, p. 15, and added in

$$-1''\cdot14 - 29''\cdot17\ T - 3''\cdot76\ T^2$$

from Newcomb's corrections. The result is

$$335^\circ\ 43'\ 25''\cdot56 + (1336^{\text{rev}} + 1108390''\cdot44)\ T + 9''\cdot541\ T^2 + 0''\cdot013473\ T^3,$$

T being measured in Julian centuries from 1800 January 0·0 G.M.T.

Airy, copying from Damoiseau, 1824, uses

$$111^\circ\ 36'\ 42''\cdot8 + (1336^{\text{rev}} + 307^\circ\ 52'\ 41''\cdot6)\ T + 10''\cdot7232\ T^2 + 0''\cdot019361\ T^3,$$

the epoch being 1801 January $0^{\text{d}}\cdot5$ Paris Mean Time, which Airy takes as being $9^{\text{m}}\ 21^{\text{s}}\cdot5$ in advance of Greenwich Mean Time.

The excess, therefore, of the Hansen-Newcomb mean longitude over the Airy-Damoiseau is

$$-3''\cdot14 + 28''\cdot63\ T - 1''\cdot1828\ T^2 - 0''\cdot005888\ T^3.$$

I neglect the cube term and transform the other terms into

$$-3''\cdot14 + 0''\cdot3246\ (p-44) - 0''\cdot0001518\ (p-44)^2$$

for the middle of my *p*th period. The precise definition of my periods is given at the top of page 421, vol. lxiv.

Table III. gives for each period from 86 to 133 the mean error, tabular *minus* observed, of the Moon's longitude, the tabular places being based on Hansen's tables, but modified as described in vol. lxiv. pp. 85, 414, 415.

Periods 86–89 (years 1847 to 1851) form part of both tables, and to call attention to this I have inclosed the errors for these periods in brackets. It will be noticed that the two sets of errors for these four periods do not agree. This is partly due to differences in the tabular places depending on such arguments as ☊, $2M-E$, $\omega-\omega'$, &c., but I have not succeeded in reconciling the two sets of figures completely.

4	+23	− 9	+14	49
5	+ 7	− 6	+ 1	50
6	+13	− 3	+10	51
7	+12	0	+12	52
8	+17	+ 3	+20	53
9	+11	+ 5	+16	54
10	+15	+ 8	+23	55
11	+11	+10	+21	56
12	+21	+13	+34	57
13	−11	+15	+ 4	58
14	+ 8	+17	+25	59
15	+ 6	+19	+25	60
16	− 3	+21	+18	61
17	−20	+23	+ 3	62
18	−32	+24	− 8	63
19	−14	+26	+12	64
20	−10	+27	+17	65
21	−29	+29	0	66
22	−38	+31	− 7	67
23	−48	+31	−17	68
24	−38	+32	− 6	69
25	−42	+33	− 9	70
26	−61	+34	−27	71
27	−36	+35	− 1	72
28	−23	+36	+13	73
29	−40	+37	− 3	74
30	−32	+37	+ 5	75
31	−29	+38	+ 9	76

[redacted]

TABLE III.

Errors, Tabular minus *Observed, of Moon's Longitude. Unit* 0″·1.
Periods 86–133.

Period.	85 +	101 +	117 +
+1	(+ 6)	−30	+ 5
2	(− 4)	−18	+ 2
3	(−12)	−10	+ 7
4	(−18)	−17	+ 9
5	−23	−14	+10
6	−26	+ 1	+ 4
7	−29	+ 2	+ 7
8	−26	+ 3	+14
9	−33	+ 2	+10
10	−43	+ 2	0
11	−47	+ 3	− 4
12	−53	−10	−10
13	−63	−13	−18
14	−58	− 8	−18
15	−50	−10	−15
16	−37	+ 1	−19

Table IV. gives the sum of my empirical formula and the last column of Table II. Table V. gives the sum of my empirical formula and Table III. Tables IV. and V. are arranged in columns of sixteen periods to exhibit the fact that the errors still outstanding seem to be principally errors of comparatively short period, depending on such arguments as ☊, $2\varpi - 2J$, 2M−E, &c. The change of phase between Tables IV. and V. is due to the large difference in the figure of Earth terms (argument ☊) in the two sets of tabular places.

TABLE IV.

Errors for each Period of Analysis corrected for Empirical Terms. 1750–1851.
Unit 0″·1.

Period.	0. +	16. +	32. +	48. +	64. +	80. +
+1	+28	− 5	+14	+15	0	+10
2	− 7	−14	− 9	+ 6	− 4	+ 8
3	− 3	+ 8	− 4	+ 6	− 7	+ 6
4	− 2	+15	−15	−13	−16	− 6
5	−17	0	−16	−18	− 9	+ 8
6	−10	− 5	−20	− 3	−22	(+ 8)

14	+10	+12	+12	+1
15	+12	+15	+ 3	
16	+ 7	+11	+10	+

TABLE V.

Errors for each Period of Analysis corrected for Emp
Unit 0″·1.

Period.	85. +	101 +
+1	(+20)	+ 2
2	(+14)	+12
3	(+ 9)	+17
4	(+ 6)	+ 7
5	+ 5	+ 6
6	+ 5	+18
7	+ 4	+16
8	+ 8	+15
9	+ 3	+11
10	− 5	+ 8
11	− 9	+ 6
12	−15	+ 4
13	−26	−12
14	[illegible]	

TABLE VI.

Mean Error, Tabular minus *Observed, of Moon's Longitude.* Smoothed.
Unit 0″·1.

Period.	0. +	32. +	64. +	96. +
3	...	0	+33	−33
7	+16	+5	+28	−25
11	+14	+11	+23	−15
15	+12	+17	+17	−5
19	+5	+25	+4	+1
23	+1	+30	−9	+2
27	−1	+31	−26	0
31	−6	+32	−34	−2

It is these thirty-one numbers in Table VI. that form the subject of the following analysis. It is required to find an empirical formula for these observed quantities.

Now at the outset every element of an empirical term is arbitrary, coefficient, period, and phase. It is at any rate possible to avoid uncertainties of phase in the following way. I add and subtract the errors equidistant from the middle or period 67. The added errors (ϵ_t) must be satisfied by an empirical formula consisting of cosines only; the subtracted errors (ϵ_t') by sines only. As I have not divided by 2 the unit is now 0″·05. The time is now measured from period 67 (or 1826·1) in units of forty periods, or forty-five years.

TABLE VII.

Values of ϵ_t. *Unit* 0″·05.

$10t$.	ϵ_t	$10t$.	ϵ_t	$10t$.	ϵ_t	$10t$.	ϵ_t
0	+66	4	+29	8	−33	12	+6
1	+60	5	+8	9	−31	13	+14
2	+54	6	−15	10	−16	14	+14
3	+47	7	−29	11	−4	15	+14

TABLE VIII.

Values of ϵ'_t. *Unit* 0″·05.

$10t$.	ϵ'_t	$10t$.	ϵ'_t	$10t$.	ϵ'_t	$10t$.	ϵ'_t
		4	−21	8	−33	12	−4
1	−4	5	−26	9	−19	13	−10
2	−8	6	−37	10	−14	14	−14
3	−13	7	−39	11	−6	15	−18

The ranges in the two tables are respectively 99 and 39. It is clearly better therefore to begin with the Even Function Analysis.

When a period is known, and its coefficient alone is required, the argument being at, it is usual to multiply each error by $\cos at$ (or $\sin at$, as the case may be), and deduce the coefficient from the sum of the products

$$\Sigma\epsilon \cos at.$$

Now suppose a term $b\cos\beta t$ added to the tabular places, and therefore to each quantity ϵ_t. The above expression then receives the increment

$$b\Sigma \cos at \cos\beta t$$

and the method breaks down unless there is reason to suppose $\Sigma \cos at \cos\beta t$ is zero, or at any rate small.

Now when a is very large and the analysis extends over many hundred periods of at, and at least one complete period of $(a-\beta)t$, the process is unobjectionable. Even then, as I have pointed out in vol. lxiv. p. 413,

$$\Sigma \sin\theta \sin(\theta \pm D)$$

is not zero when the summation extends over observations for which D is never zero, and for which $\cos D$ averages $-\frac{1}{2}$; but an approximate allowance can be made in such cases.

When, however, a is very small, and we have only two periods of at, extreme caution is required.

Supposing, for instance, the coefficient of $\sin at$ is required from observations that extend over two revolutions of the argument from $at = -360°$ to $at = +360°$, and a term $5'' \sin\frac{1}{4}at$ exists in the errors.

If the coefficient of $\sin at$ be taken as the mean value of $2\epsilon \sin at$, the result is in error by $10'' \times$ mean value of $\sin at \sin\frac{1}{4}at$, which works out to about $2''$.

Now this illustration is very much in point, for I am trying to prove the existence of a 66-year term which goes through two revolutions in 150 years, and Newcomb's empirical term corresponds closely to the term $\frac{1}{4}at$, a term with four times the period. Also I believe that Newcomb's term should be replaced by one with a period 30 per cent. longer. My estimate of the errors of Newcomb's term is given in the fourth column of Table I., but the possibility of even larger errors must be borne in mind. A maximum error of $5''$ may, in certain circumstances as to phase, cause an error of $2''$ in the deduced coefficient of a 66-year term.

Table IX. tabulates for values of a proceeding by intervals of 10° from 10° to 900° t the values of $\Sigma\epsilon_t \cos at$, the summation extending over all the values of ϵ_t in Table VII.

[redacted]

Table IX.

$\frac{1}{10}a$.	$\Sigma\epsilon_t \cos at$.	$\frac{1}{10}a$.	$\Sigma\epsilon_t \cos at$.	$\frac{1}{10}a$.	$\Sigma\epsilon_t \cos at$.	$\frac{1}{10}a$.	$\Sigma\epsilon_t \cos at$.
1°	+184	24°	+308	46°	−31	68°	+29
2	+183	25	+299	47	−22	69	+32
3	+182	26	+286	48	−12	70	+35
4	+181	27	+267	49	− 2	71	+38
5	+180	28	+247	50	+ 6	72	+40
6	+179	29	+221	51	+16	73	+44
7	+182	30	+194	52	+21	74	+44
8	+182	31	+164	53	+27	75	+47
9	+185	32	+134	54	+28	76	+48
10	+189	33	+104	55	+33	77	+46
11	+196	34	+ 76	56	+32	78	+45
12	+205	35	+ 47	57	+33	79	+42
13	+217	36	+ 26	58	+30	80	+40
14	+229	37	+ 2	59	+30	81	+38
15	+244	38	− 16	60	+27	82	+37
16	+257	39	− 30	61	+24	83	+34
17	+272	40	− 40	62	+23	84	+31
18	+285	41	− 47	63	+24	85	+29
19	+297	42	− 47	64	+22	86	+30
20	+305	43	− 48	65	+24	87	+29
21	+312	44	− 44	66	+24	88	+27
22	+314	45	− 39	67	+26	89	+30
23	+315					90	+31

The maximum at $a = 230° t$ is very striking. If $b \cos \beta t$ be added to each quantity ϵ_t, the increment of $\Sigma\epsilon_t \cos at$ is

$$8b[F(a-\beta)+F(a+\beta)]$$

when

$$F(x) = \frac{\sin \frac{16x}{20}}{16 \sin \frac{x}{20}} \cos \frac{15x}{20}$$

Table X. tabulates $10^3 . F(x)$ for each degree of $\frac{x}{10}$ from 0° to 90°.

1	+ 989	24	+ 63	47	·
2	+ 953	25	+ 98	48	-
3	+ 897	26	+ 126	49	+
4	+ 822	27	+ 145	50	+
5	+ 731	28	+ 155	51	+
6	+ 628	29	+ 156	52	+
7	+ 517	30	+ 148	53	+
8	+ 403	31	+ 132	54	+
9	+ 290	32	+ 110	55	+
10	+ 183	33	+ 84	56	+
11	+ 85	34	+ 55	57	+
12	0	35	+ 27	58	+
13	− 70	36	0	59	+
14	− 123	37	− 23	60	
15	− 159	38	− 41	61	−
16	− 177	39	− 53	62	−
17	− 179	40	− 59	63	−
18	− 166	41	− 58	64	−
19	− 141	42	− 50	65	−
20	− 107	43	− 37	66	−

would produce a maximum in Table IX. opposite its own argument far more pronounced than any effect it can produce at the point $a = 230° t$.

Table IX. is clearly not suitable for further investigation. Its ninety terms are more cumbrous in use than the sixteen terms of Table VII. The method I am now about to develop is the one by which I actually found the term $2''.3 \cos 246° t$, and the success of the method is due to the fact that it narrows the investigation from the sixteen terms of Table VII. down to four quantities, which I call x_2, x_4, x_6, x_8.

My original idea was to develop the errors in powers of the time. In the short-period terms the high powers of the time will have coefficients that rise in importance relatively to the coefficients of the long-period terms. In fact

$$\cos pt = 1 - \tfrac{1}{2}p^2t^2 + \tfrac{1}{24}p^4t^4 - \tfrac{1}{720}p^6t^6 + \tfrac{1}{40320}p^8t^8$$

and the method in its simplest form is to take advantage of the factor p^8 in the coefficient of t^8. It was convenient, however, to make one modification. If we equate the errors first to

$$a + \beta t^2 + \gamma t^4$$

and next to

$$a + \beta t^2 + \gamma t^4 + \delta t^6$$

we shall not get the same values of a, β, γ when we introduce δt^6 as when we omit it. In other words, if we form normal equations for a, β, γ, δ the cross terms do not vanish. I have remedied this inconvenience by resolving for quantities x_0, x_1, . . . x_9, instead of coefficients of the powers of t. The error for any value of t is equated to $\Sigma_r x_r t_r$ when t_r is rational integral algebraic function of t of the rth degree defined by the conditions

$$\Sigma_t t_r t_s = 0 \text{ when } r-s \text{ is even, } \Sigma_t t_r^2 = 1.$$

The odd and even powers of t can be separated as before, and the quantities given in Tables IV. and V. are still those appropriate to even and odd function analysis. The summation Σ extends over the sixteen values of $10t$ from 0 to 15.

t_{2r} will consist of even powers of t only; t_{2r+1} of odd powers only. When the quantities t_r have been calculated, first in powers of t and then numerically for different values of t, we have

$$x_{2r} = \Sigma\epsilon_t \,.\, t_{2r} \text{ from Table VII.}$$

$$x_{2r+1} = \Sigma\epsilon_t' t_{2r+1} \text{ from Table VIII.}$$

and the probable errors of the quantities x are equal to those of the quantities ϵ_t.

Now, for the calculation of the quantities t_r, let S_{2m} denote Σt^{2m}, so that

$$S_0 = 16,\ S_2 = 12.4 \text{ \&c.}$$

Consider the two determinants

$$\begin{vmatrix} S_{18} & S_{16} & S_{14} & S_{12} & S_{10} & S_{8} \\ S_{16} & S_{14} & S_{12} & S_{10} & S_{8} & S_{6} \\ S_{14} & S_{12} & S_{10} & S_{8} & S_{6} & S_{4} \\ S_{12} & S_{10} & S_{8} & S_{6} & S_{4} & S_{2} \\ S_{10} & S_{8} & S_{6} & S_{4} & S_{2} & S_{0} \end{vmatrix}$$

obtained by suppressing the first or last column in the above form. From the former, when the first column is suppressed, the coefficients of t_8 in powers of t can be calculated, and from the latter the coefficients of t_9. The formulæ are perfectly general, but I have not gone beyond t_9.

Let $D_{2m.2n.2p}$ denote a determinant of three rows and columns, three being the number of suffixes chosen for illustration, built up on S_{2m}, S_{2n}, S_{2p} as a base, and the elements standing in the line above having suffixes greater by 2, and in the line above that greater by 4, then

$$t_9 = D_{8.6.4.2}t^9 - D_{10.6.4.2}t^7 + D_{10.8.4.2}t^5 - D_{10.8.6.2}t^3 + D_{10.8.6.4}t$$

divided by $\{D_{10.8.6.4.2}D_{8.6.4.2}\}^{\frac{1}{2}}$

and $t_8 = D_{6.4.2.0}t^8 - D_{8.4.2.0}t^6 + D_{8.6.2.0}t^4 - D_{8.6.4.0}t^2 + D_{8.6.4.2}$

divided by $\{D_{8.6.4.2.0} \cdot D_{6.4.2.0}\}^{\frac{1}{2}}$

These formulæ follow easily from the definitions of t_9 and t_8, and analogous formulæ for t_7 are obvious.

We have

$S_{18} = 2050{\cdot}579$	$S_{10} = 110{\cdot}65327$	$S_2 = 12{\cdot}4$
$S_{16} = 965{\cdot}4783$	$S_8 = 56{\cdot}66482$	$S_0 = 16$
$S_{14} = 460{\cdot}3402$	$S_6 = 30{\cdot}48292$	
$S_{12} = 223{\cdot}1603$	$S_4 = 17{\cdot}8312$	

The value of $D_{10.8.6.4.2}$ turns out to be about 10, and the value of $D_{8.6.4.2.0}$ about 100. As the values of the leading terms in the determinants as they stand are about 2×10^{10} and 4×10^9, it is clear that some modifications must be introduced before numerical calculation. I therefore divided the rows and columns of the determinants by successive powers of 2, beginning with the last column and the lowest row. I then subtracted from each row above the first the row immediately below it. These two modifications only alter the determinants and minors by some power of 2. The calculations now just fall within the compass of seven-figure logarithms when performed according to the direct rules. I give below the elements of the new determinants with their logarithms written below :—

8409 , +0·043748o4 , +0·027381968, +0·007241247, −0·020909214, −0·067203389
i64798]

1374804 , +0·027381968, +0·007241247, −0·020909214, −0·067203389, −0·16185875
109586]

27381968, +0·007241247, −0·020909214, −0·067203389, −0·16185875 , −0·43555
374647]

07241247, −0·020909214, −0·067203389, −0·16185875 , −0·43555 , −2·45
598133] , [8·3203377] , [8·8273912] , [9·2091362] , [9·6390380]

6447865 , 0·88538786 , 0·95259125 , 1·11445 , 1·55 , 4·0
367542] , [9·9471336] , [9·9789066] , [0·0470606]

I use $\Delta_{2m.2n.2p}$, with a definition similar to $D_{2m.2n.2p}$. We have

$$D_{2m.2n.2p} = 2_{m+4+n+3+p+2}\Delta_{2m.2n.2p},$$

whence

$$t_9 = \Delta_{8.6.4.2}t^9 - 2\Delta_{10.6.4.2}t^7 + 2^2\Delta_{10.8.4.2}t^5 - 2^3\Delta_{10.8.6.2}t^3 + 2^4\Delta_{10.8.6.4}t$$

divided by $\{2^{11}\,.\,\Delta_{10.8.6.4.2}\,.\,\Delta_{8.6.4.2}\}^{\frac{1}{2}}$

and

$$t_3 = \Delta_{6.4.2.0}t^8 - 2\,.\,\Delta_{8.4.2.0}t^6 + 2^2\Delta_{8.6.2.1}t^4 - 2^3\Delta_{8.6.4.0}t^2 + 2^4\Delta_{8.6.4.2}$$

divided by $\{2^{10}\,.\,\Delta_{8.6.4.2.0}\,.\,\Delta_{6.4.2.0}\}^{\frac{1}{2}}$.

As the calculation is a very long one, I give an outline of it.

$\Delta_{2.0}$	= −1·7422	+3·7975	= 2·0553	= [0·3128752]
$\Delta_{4.0}$	= −0·6474350	+2·7304025	= 2·0829675	= [0·3186825]
$\Delta_{6.0}$	= −0·2688136	+2·3338486	= 2·0650350	= [0·3149275]
$\Delta_{8.0}$	= −0·0836369	+2·1692003	= 2·0855634	= [0·3192234]
$\Delta_{4.2}$	= −0·2508811	+0·4853988	= 0·2345176	= [9·3701755]
$\Delta_{6.2}$	= −0·1041652	+0·4149011	= 0·3107359	= [9·4923914]
$\Delta_{8.2}$	= −0·0324093	+0·3856307	= 0·3532214	= [9·5480470]
$\Delta_{10.2}$	= +0·0112239	+0·3765236	= 0·3877475	= [9·5885490]
$\Delta_{6.4}$	= −0·07489483	+0·15418524	= 0·07929041	= [8·8992207]
$\Delta_{8.4}$	= −0·02330228	+0·14330778	= 0·12000550	= [9·0792011]
$\Delta_{10.4}$	= +0·00807001	+0·13992342	= 0·14799343	= [9·1702424]
$\Delta_{8.6}$	= −0·01991794	+0·05950107	= 0·03958313	= [8·5975101]
$\Delta_{10.6}$	= +0·00689795	+0·05809589	= 0·06499384	= [8·8128722]
$\Delta_{10.8}$	= +0·00641131	+0·01807557	= 0·02448688	= [8·3889335]

$\Delta_{4.2.0}$	$= 10^{-7}\{$ −1381231 +	3371465 −	1021441 =	968793$\}$	= [8·9862310]
$\Delta_{6.2.0}$	$= 10^{-7}\{$ − 429747 +	3342441 −	1353410 =	1559284$\}$	= [9·1929250]
$\Delta_{8.2.0}$	$= 10^{-7}\{$ + 148829 +	3375667 −	1538456 =	1986040$\}$	= [9·2979880]
$\Delta_{6.4.0}$	$= 10^{-8}\{$ −4355321 +	13877737 −	3453495 =	6068921$\}$	= [8·7831114]
$\Delta_{8.4.0}$	$= 10^{-8}\{$ +1508328 +	14015694 −	5226839 =	10297182$\}$	= [9·0127184]
$\Delta_{8.6.0}$	$= 10^{-3}\{$ +1495343 +	4360749 −	1724043 =	4132049$\}$	= [8·6161654]

$$\Delta_{6.4.2} = 10^{-9}\{-4903580+20882505-12833849= 3145076\} = [7{\cdot}4976312]$$
$$\Delta_{8.4.2} = 10^{-9}\{+1698200+23737678-19423937= 6011941\} = [7{\cdot}7790147]$$
$$\Delta_{10.4.2} = 10^{-8}\{+ 642155+ 2605795- 2395403= 852547\} = [7{\cdot}9307184]$$
$$\Delta_{8.6.2} = 10^{-9}\{+2250115+ 7385581- 6406876= 3228820\} = [7{\cdot}5090438]$$
$$\Delta_{10.6.2} = 10^{-8}\{+ 850856+ 810749- 1051982= 609623\} = [7{\cdot}7850614]$$
$$\Delta_{10.8.2} = 10^{-9}\{+9671898- 2807774- 3963416= 2900708\} = [7{\cdot}4625040]$$
$$\Delta_{8.6.4} = 10^{-9}\{+ 574161+ 2509219- 2660120= 423260\} = [6{\cdot}6266072]$$
$$\Delta_{10.6.4} = 10^{-9}\{+2171128+ 3094426- 4367807= 897747\} = [6{\cdot}9531540]$$
$$\Delta_{10.8.4} = 10^{-9}\{+3285987- 1071657- 1645602= 568728\} = [6{\cdot}7549046]$$
$$\Delta_{10.8.6} = 10^{-9}\{+1083864- 470636- 512001= 101227\} = [6{\cdot}0052964]$$

$$\Delta_{6.4.2.0} = 10^{-9}\{+ 701527+3260338-4078520+ 509058=392403\} = [6{\cdot}5937323]$$
$$\Delta_{8.4.2.0} = 10^{-9}\{+2652746+4152654-6920056+ 973085=858429\} = [6{\cdot}9337044]$$
$$\Delta_{8.6.2.0} = 10^{-9}\{+4269625-1438140-2776877+ 522613=577221\} = [6{\cdot}7613422]$$
$$\Delta_{8.6.4.0} = 10^{-9}\{+1661790- 745644- 863979+ 68508=120675\} = [6{\cdot}0816173]$$
$$\Delta_{8.6.4.2} = 10^{-11}\{+8611840-4353394-6751208+2844450=351688\} = [4{\cdot}5461575]$$
$$\Delta_{10.6.4.2} = 10^{-10}\{+1375909- 617350-1274674+ 603316= 87201\} = [4{\cdot}9405215]$$
$$\Delta_{10.8.4.2} = 10^{-10}\{+2630106-2334442- 606515+ 382204= 71353\} = [4{\cdot}8534122]$$
$$\Delta_{10.8.6.2} = 10^{-10}\{+1412545-1669268+ 210047+ 68028= 21352\} = [4{\cdot}3294386]$$
$$\Delta_{10.8.6.4} = 10^{-10}\{+1851680-2458208+ 411830+ 211658= 16960\} = [3{\cdot}2294258]$$

$$\Delta_{8.6.4.2.0} = 10^{-11}\{+1716686-2350548+ 417980+ 252319- 23635=12802\} = [3{\cdot}1072$$
$$\Delta_{10.8.6.4.2} = 10^{-11}\{+ 20542- 38149+ 19538- 1546- 355= 30\} = [0{\cdot}4771$$

whence

$$t_0 = 0{\cdot}25$$
$$t_1 = 0{\cdot}2840\ t$$
$$t_2 = \underset{[9\cdot54253]}{0{\cdot}3488}\ t^2 - 0{\cdot}2703$$
$$t_3 = \underset{[9\cdot65750]}{0{\cdot}454}\ t^3 - 0{\cdot}6535\ t$$
$$t_4 = \underset{[9\cdot76023]}{0{\cdot}5768}\ t^4 - \underset{[0\cdot06707]}{1{\cdot}1670}\ t^2 + 0{\cdot}2628$$
$$t_5 = \underset{[9\cdot88267]}{0{\cdot}763}\ t^5 - \underset{[0\cdot30591]}{2{\cdot}023}\ t^3 + 1{\cdot}0322\ t$$
$$t_6 = \underset{[9\cdot99213]}{0{\cdot}9820}\ t^6 - \underset{[0\cdot49985]}{3{\cdot}1612}\ t^4 + \underset{[0\cdot39107]}{2{\cdot}4608}\ t^2 - 0{\cdot}2550$$
$$t_7 = \underset{[0\cdot12110]}{1{\cdot}322}\ t^7 - \underset{[0\cdot70352]}{5{\cdot}053}\ t^5 + \underset{[0\cdot73457]}{5{\cdot}427}\ t^3 - 1{\cdot}4229\ t$$
$$t_8 = \underset{[0\cdot23808]}{1{\cdot}7301}\ t^8 - \underset{[0\cdot87908]}{7{\cdot}5697}\ t^6 + \underset{[1\cdot00775]}{10{\cdot}1800}\ t^4 - \underset{[0\cdot62905]}{4{\cdot}2565}\ t^2 + 0{\cdot}2481$$
$$t_9 = \underset{[0\cdot37885]}{2{\cdot}3925}\ t^9 - \underset{[1\cdot07425]}{11{\cdot}8644}\ t^7 + \underset{[1\cdot28817]}{19{\cdot}4164}\ t^5 - \underset{[1\cdot06522]}{11{\cdot}6208}\ t^3 + 1{\cdot}8460\ t$$

and the numerical values are given in Table XI.

TABLE XI.

Values of $t_0, t_1 \ldots t_9$ *in Units of* 0·001.

10t.	t_1.	t_3.	t_5.	t_7.	t_9.
1	+ 28	− 64	+ 101	− 137	+ 173
2	+ 57	− 127	+ 190	− 244	+ 282
3	+ 85	− 184	+ 258	− 293	+ 284
4	+ 114	− 232	+ 291	− 272	+ 175
5	+ 142	− 270	+ 287	− 181	− 11
6	+ 170	− 294	+ 241	− 38	− 200
7	+ 199	− 301	+ 157	+ 126	− 311
8	+ 227	− 290	+ 40	+ 262	− 278
9	+ 256	− 257	− 95	+ 323	− 93
10	+ 284	− 199	− 228	+ 273	+ 169
11	+ 312	− 114	− 328	+ 97	+ 354
12	+ 341	+ 1	− 357	− 166	+ 282
13	+ 369	+ 150	− 268	− 393	− 113
14	+ 398	+ 332	0	− 343	− 514
15	+ 426	+ 554	+ 518	+ 394	+ 253

10t.	t_0.	t_2.	t_4.	t_6.	t_8.
0	+ 250	− 270	+ 263	− 255	+ 248
1	+ 250	− 266	+ 251	− 230	+ 206
2	+ 250	− 256	+ 217	− 162	+ 94
3	+ 250	− 238	+ 163	− 59	− 59
4	+ 250	− 214	+ 91	+ 62	− 202
5	+ 250	− 183	+ 7	+ 177	− 291
6	+ 250	− 144	− 82	+ 267	− 289
7	+ 250	− 99	− 171	+ 308	− 185
8	+ 250	− 47	− 248	+ 282	− 1
9	+ 250	+ 13	− 304	+ 186	+ 201
10	+ 250	+ 79	− 328	+ 27	+ 332
11	+ 250	+ 152	− 306	− 165	+ 302
12	+ 250	+ 232	− 224	− 334	+ 64
13	+ 250	+ 319	− 65	− 384	− 295
14	+ 250	+ 414	+ 188	− 182	− 452
15	+ 250	+ 515	+ 552	+ 464	+ 325

Table XII. now gives x_2, x_4, x_6, x_8 for the quantities ϵ_t and for various comparison terms. Table XIII. gives x_1, x_3, x_5, x_7, x_9 for the quantities ϵ'_t and for the *corresponding* comparison terms.

	[illegible]	+ 130
$1000 \cos 120^\circ t$	−2787	+ 853
$1000 \cos 180^\circ t$	−1536	+2198
$1000 \cos 200^\circ t$	− 693	+2445
$1000 \cos 220^\circ t$	+ 111	+2459
$1000 \cos 230^\circ t$	+ 449	+2365
$1000 \cos 240^\circ t$	+ 726	+2202
$1000 \cos 250^\circ t$	+ 931	+1979
$1000 \cos 260^\circ t$	+1056	+1703
$1000 \cos 280^\circ t$	+1060	+1020
$1000 \cos 320^\circ t$	+ 305	− 404
$1000 \cos 330^\circ t$	+ 42	− 680
$1000 \cos 340^\circ t$	− 220	− 900
$1000 \cos 360^\circ t$	− 666	−1131
$1000 \cos 390^\circ t$	− 981	− 935
$1000 \cos 400^\circ t$	− 971	− 749
$1000 \cos 410^\circ t$	− 899	− 520
$1000 \cos 438^\circ t$	− 489	+ 225

TABLE XIII.

Values of x_1, x_3, x_5, x_7, x_9 for the Moon and Com

	x_1.	[illegible]	[illegible]
ϵ'_t	− 58	+ 40	−
$1000 \sin 45^\circ t$	+2378	− 162	+
$1000 \sin 50^\circ t$	+2548	− 218	+

	x_1.	x_3.	x_5.	x_7.	x_9.
1000 sin 250° t	− 835	− 345	+ 2286	− 1092	+ 224
1000 sin 260° t	− 630	+ 44	+ 2264	− 1264	+ 291
1000 sin 280° t	− 138	+ 714	+ 2043	− 1603	+ 456
1000 sin 320° t	+ 636	+ 1269	+ 975	− 2085	+ 947
1000 sin 330° t	+ 721	+ 1219	+ 626	− 2122	+ 1092
1000 sin 340° t	+ 753	+ 1096	+ 270	− 2118	+ 1245
1000 sin 360° t	+ 656	+ 688	− 404	− 1966	+ 1542
1000 sin 390° t	+ 232	− 108	− 1115	− 1377	+ 1903
1000 sin 400° t	+ 9	− 357	− 1233	− 1102	+ 1977
1000 sin 410° t	− 171	− 569	− 1278	− 804	+ 2017
1000 sin 438° t	− 476	− 898	− 1049	+ 85	+ 1937

From Table XII.

	x_2.	x_4.	x_6.	x_8.
ϵ_1	− 43	+ 93	− 70	+ 14
− 12″·2 cos 60° t... ...	+ 316	− 19		
Sum	+ 273	+ 74	− 70	+ 14
+ 15″·0 cos 45° t	− 237	+ 8		
− 1·95 cos 246 t ...	− 33	− 80	+ 70	− 20
+ 0·15 cos 390 t ...	− 3	− 2	0	+ 6
Sum	0	0	0	0

From Table XIII.

	x_1.	x_3.	x_5.	x_7.	x_9.
ϵ_1	− 58	+ 40	− 33	− 4	+ 18
− 9″·5 sin 60° t	+ 532	− 69	+ 2	− 1	− 2
Sum ...	+ 474	− 29	− 31	− 5	+ 16
− 9″·7 sin 45° t	− 464	+ 32			
− 0·43 sin 246 t	− 8	− 4	+ 20	− 9	+ 2
− 0·50 sin 390 t	− 2	+ 1	+ 11	+ 14	− 19
Sum ...	0	0	0	0	0

At the beginning of the analysis I took means for 17 consecutive periods. The effect of this is to diminish the coefficient of any 42-year term in the ratio 1·4 to 1, and the coefficient of any 66-year term in the ratio 1·17 to 1. Multiplying by these ratios, the empirical formula that I have given at the beginning of this paper is shown to be a solution of the observed values of the quantities x.

I give a brief outline of the investigation by which I sought a solution for the observed x's. I can only add that throughout

E 2

the entire calculations I saw no alternative to my conclusions on the supposition that the x's are free from accidental error, and no reason to suppose that small errors in the x's will produce other than small variations in the solution.

If means for 17 consecutive periods be taken in Tables IV. or V. it will be seen that, when cleared of short-period terms, the errors of the Moon are reduced to such small quantities that the probable error of the quantities ϵ_t, ϵ'_t, each representing about 2000 observations, may be taken as $0''\cdot 2$ or 4 units.

The probable error of an x is equal to that of a quantity ϵ_t or ϵ'_t.

Hence the probable error of the x's is about 4. The observed values of x_5, x_6, x_8, x_9 are certainly real and not accidental, and the existence of at least one term of moderate period is therefore demonstrated.

Again, a comparison of x_5, x_7, x_9 with the comparison terms of Table XIII. proves the existence of at least two terms of moderate period, for no single term bears sufficient resemblance to ϵ'_t.

From the values of x_6, x_8 and from Table IX. I infer that one term of moderate period has an argument approximating to $230° t$.

An attempt to work with $2''\cdot 5 \cos 220° t$ fails, on account of the large value of x_4 left when $2''\cdot 5 \cos 220° t$ is taken out.

A large value of x_4 implies a large coefficient in the long-period term; this will leave x_2 large, and an enormous secular term would have to be called in to explain x_2. All this can be avoided by increasing the argument to $246° t$.

Coming now to ϵ'_t, the odd function analysis, my search proceeded thus:—I took out a small term $k \sin 246° t$, so as to reduce x_7 to zero, and I got a certain ratio between the coefficients of x_5 and x_9. I then took out from the x's for $1000 \sin 246° t$ the x's for $A \sin a t$, giving a different values, and always giving A such a value that x_7 was zero for $1000 \sin 246° t - A \sin a t$, and I took different values of a, until at last the ratio $x_5 : x_9$ was the same as for $\epsilon'_t - k \sin 246° t$. I thus found the argument $390° t$, and I then imported it into the even function analysis, to reduce the value of x_8.

Meanwhile I was also making the assumption that only one long-period empirical term was to be introduced. First I tried $60° t$; *i.e.* I permitted to myself alterations of the coefficients of Newcomb's empirical term, but no alteration of its period. I was led to $9''\cdot 2 \cos 60° t$, an alteration of $3''$ in the even part of Newcomb's term. This coefficient $9''\cdot 2$ is determined by the value of x_2: it implies a definite value of x_4, and everything can be adjusted for 150 years (1750 to 1901) by taking $240° t$ instead of $246° t$. The solution, however, breaks down when the numerical values are calculated for $t = -2, -3, -4$ or the years 1736, 1691, 1646. I should say that the coefficient of the sine term is found from x_3, and any outstanding part of x_1 can be ascribed to a mean motion.

Table XIV. gives an outline of the result of taking various arguments for the long-period term, and permitting no alteration of the secular term.

TABLE XIV.

Correction to Hansen-Newcomb.				Values for	
			$t=-2.$	$t=-3.$	$t=-4.$
$+3''.5 - 12''.2 \cos 60^\circ t + 9''.5 \sin 60^\circ t$		$+ 7''.5 \cos 70^\circ t - 3''.0 \sin 70^\circ t - 3''.9\, t$	$+5''.4$	$+19''.4$	$+31''.7$
$+1.5$	„ „	$+ 9.2 \cos 60\, t - 4.5 \sin 60\, t - 3.0\, t$	$+4.6$	$+13.4$	$+19.3$
-1.6	„ „	$+ 12.5 \cos 50\, t - 6.7 \sin 50\, t - 1.8\, t$	$+4.3$	$+8.5$	$+5.9$
-4.3	„ „	$+ 15.2 \cos 45\, t - 9.0 \sin 45\, t - 0.5\, t$	$+3.6$	$+5.0$	-3.2

It will be seen that the argument $60^\circ\, t$ leads to errors of $20''$ about 1650, and that $70^\circ\, t$ (which is approximately Hansen's argument that Professor Newcomb removed) is worse; $50^\circ\, t$ is better and $45^\circ\, t$ will do.

Since Table XIV. was computed the coefficients have undergone slight adjustments. In particular $-0.5\, t$ has been replaced by $-0''.7 \sin 45^\circ\, t$, from which it is, of course, indistinguishable during modern times.

Finally, having at length obtained long-period terms

$$15.0 \cos 45^\circ\, t - 9''.7 \sin 45^\circ\, t,$$

that will satisfy the data before 1750 reasonably well, and which will satisfy with rigour the requirements of the period 1750 to 1901, it remains to point out what latitude is still permissible, or, in other words, to what extent the solution is not unique.

The above formula may be expanded in powers of t, and it will be found that the term in t^6 is insensible from 1650 onwards, and that the term in t^5 is so small that its variations as the formula is changed are insensible. We are then left with t, t^2, t^3, and t^4. Any part of the coefficient of t^2 may be ascribed to a secular term; the ratio of the coefficients of t^2 and t^4 will then determine the period. The period being known the coefficient of t^3 determines the coefficient of the sine term, and the t term is a mean motion. In this way the statement at the beginning of the paper was deduced, showing that twice the probable correction to the secular acceleration only alters the period from 363 years to 327 years. A small error in the observed x_4 will naturally produce some effect on the period, but the main conclusion is, I think, made out, that in addition to certain terms of moderate periods the tables require a substitution of a term of longer period for that of Professor Newcomb's.

a Possible Source of Error in Measures of Star Places to Defective Centring of the Object Glass. By H. H. er, D.Sc., F.R.S., Savilian Professor.

ne object of this note is to call attention to the possible e of a kind of error which has not, so far as I know, herto noticed. It was suggested by the occurrence of a able systematic difference, varying with the magnitude of between star-places derived from photographs taken with nstruments at Algiers and at Paris, for the parallax of ee pp. 38–40 of the 11th Circular. I have at present no f knowing whether the following is the true cause of these es, but it seems to me to be at least a possible cause, and h may produce small systematic errors in general.

f the two lenses of an object glass are not correctly i.e. if their optical axes do not truly coincide, the image r will be a small spectrum. For simplicity suppose there colours, red and blue, side by side. For a faint star the will not affect the plate, and the image will be formed by s only. But for bright stars both blue and red will affect e, and the centre of the image will therefore be displaced the red end as compared with the image for faint stars.

the corresponding images are juxtaposed all over the plate. We thus had a ready means of testing the existence of this error in the Oxford glass at once. The plate was partially measured by Mr. B. Gray on November 7 and 8, taking, in the first instance the three bands across the plate between the values $y=0·0$ to $5·0$, $y=11·0$ to $15·0$, $y=21·0$ to $26·0$ (*i.e.* two outside strips and one central), and afterwards the omitted portions, $y=5·0$ to $11·0$ and $y=15·0$ to $21·0$. A comparison of the two sets gives a general check on the results, but has no particular significance.

The differences (corrected by linear corrections of the simple form $\Delta x = by + c$, $\Delta y = -bx + f$) were grouped according to the diameters of the photographic images and gave the following mean results :—

Plate 1623. *R.A.* 21^h 18^m $+30°$.

Mean Diam. of Image.	No. of Stars. (First Set)	Δx. (First Set)	Δy. (First Set)	No. of Stars. (Second Set)	Δx. (Second Set)	Δy. (Second Set)	Δx. (Mean)	Δy. (Mean)	Total Stars.
″		″	″		″	″	″	″	
30	93	−0·06	−0·09	72	+0·03	0·00	0·00	−0·03	165
45	57	+ ·21	− ·12	61	+ ·21	+ ·12	+ ·21	·00	118
60	38	+ ·15	− ·27	34	+ ·12	+ ·18	+ ·12	− ·06	72
78	17	+ ·21	− ·12	16	+ ·18	+ ·03	+ ·21	− ·03	33
99	11	− ·12	+ ·06	9	·00	+ ·09	− ·06	+ 0·9	20
140	5	− ·54	+ ·18	5	− ·66	− ·18	− ·57	·00	10

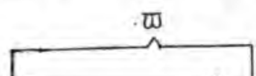
6. There seems to be possibly a sensible effect of the kind under consideration in the x coordinate ; but it must be remembered that the results for a single plate may be affected by "driving-error," and a systematic effect due to the objective can only be established by measuring a number of plates.

7. Finally, it is to be remarked that any error of this kind is likely to be altered when the lenses of the objective are separated for cleaning. Now I have published two papers (see *Monthly Notices*, lxiii. p. 56 and lxiv. p. 3) on the proper motions of bright stars relatively to faint stars, deduced from a comparison of measures made on plates taken at the University Observatory about 1893 and about 1898. At the time of writing them I did not know of any source of instrumental error likely to affect the results ; but, since the lenses of the objective were separated for cleaning in 1894 July, it seems now possible that the results given in the two papers above quoted are affected to an unknown extent by an error of the kind now indicated, and the results therein given must be accepted with this reservation accordingly, until further examination of the point can be made.

University Observatory, Oxford :
1904 *November* 11.

ery Sensitive Method of Determining the Irregularities Pivot: on the Pivot Errors of the Radcliffe Transit le, and their Effect on the Right Ascensions of the liffe Catalogue for 1890. By Arthur A. Rambaut, ., Sc.D., F.R.S., Radcliffe Observer.

he *Monthly Notices*, lv. pp. 21 and 292, the late Mr. Stone tention to the existence of small but sensible differences the right ascensions of stars observed with the Oxford, nd Greenwich Transit Circles. In order to examine how e differences might be due, as had been suggested, to rities in the pivots of the Oxford instrument, he provided with a piece of apparatus for testing the figure of a pivot ad been devised by Monsieur M. Hamy, of the Paris tory, and described by him in the *Comptes Rendus*, No. 20, and more fully in the *Bulletin Astronomique*, 49. The result of his investigation was published by a short paper in the *Monthly Notices*, lvi. p. 338, in



pivot. This lever supports a small horizontal mirror, *m*, of black glass at a convenient distance from the fulcrum *a*. The mirror stands above and very close to the upper plane face of the lens *l* of a bent collimator provided with three levelling screws which rest on the pier. At the focus of the lens *l* is placed a small total-reflexion prism, *d*, which is illuminated from the side with monochromatic light by means of a condensing lens. When this prism is adjusted so that light enters the collimator interference fringes are produced in the lamina between the mirror *m* and the lens *l* as soon as their plane faces are brought into sensible parallelism. An eye placed at E on looking at the lens *l* as reflected in the prism D will see these fringes at one side of the prism *d*.

Things being so arranged, when the telescope is turned, the block A remains immovable, or moves slightly in an up-and-down direction, oscillating about the point *p*, according as the pivot P is, or is not, a perfect surface of revolution. In the one case

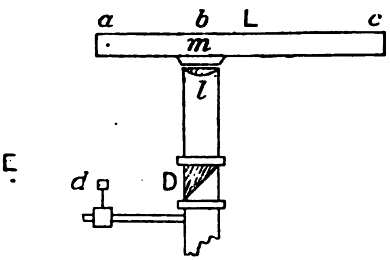


Fig. 2.

the fringes remain stationary, in the other they are displaced to a greater or less extent.

Monsieur Hamy's method is beautifully sensitive, and enables one to say almost immediately whether a pivot is sensibly true or not. As he says: "Les expériences que je vais décrire permettent de se rendre compte, en quelques instants, de l'état des tourillons d'une lunette et répondent, sur-le-champ, à la question de savoir si leur forme est assez parfaite, pour n'avoir pas à redouter d'erreur appréciable dans les mesures méridiennes."

Some time after the direction of the Radcliffe Observatory came into my hands, being anxious to make sure of this point, which seemed to me to have been rather hastily disposed of, I examined the eastern pivot with the apparatus as left by Stone, and soon detected the existence of appreciable errors which it seemed important to evaluate. The method as described by Monsieur Hamy does not, however, afford us the means of determining the amount of the errors when the pivot is found to deviate from an exactly cylindrical form, or of evaluating the effect of the errors on the time of transit of a star. For this purpose it is necessary to attack the problem in some other way.

principal methods hitherto employed are :

That of Airy, still used at the Royal Observatory, ;reenwich, and fully described in the *Greenwich Observa- ions* for 1852, Appendix I., p. {17}. It has been recently ıpplied by Sir David Gill in a slightly modified form to he Cape Transit Circle with signal success (see *Monthly Votices*, lix. p. 125) ;

That of Loewy and Périgaud, described in the Annales de 'Observatoire de Paris, *Mémoires*, xvi. ; and

That of Villarceau described at length in the Annales de 'Observatoire de Paris, *Mémoires*, vii. p. 307.

these methods entail considerable labour and long series meter measures, during which there is always the danger ges in the temperature conditions affecting the results. vas a difficulty, too, in applying any of them to the e Transit Circle, as each required a specialised apparatus was unable to provide, and I was accordingly led, in the tance, to adopt a modification of Airy's method which likely to suit the special conditions afforded by the instrument. This consisted of a plane glass mirror of s aperture, silvered on the front surface, which was

that any apparatus employed for examining the pivots must be attached to the piers themselves on which the pivots rest, and ought not to stand on a separate pier, nor to be attached to the walls of the building as the collimator had been in our first experiments. This seemed to point to Villarceau's method as the most suitable; but while considering the advisability of falling back on this a modification of Hamy's occurred to me which I decided to adopt, and which, at a very trifling cost, has enabled me to attain my object in a most satisfactory manner.

Whatever plan is adopted the essential object is to determine the movement of *any* line rigidly fixed in the material axis of the instrument with regard to *any* axes of coordinates fixed with regard to the Y's, or piers. If we could apply Hamy's method to two *points*, one at the end of each pivot, we should have the means of determining the vertical movements of the line joining them with all desirable accuracy. Or if we had two small cylinders, or pins, of perfectly circular section, one at each end of the axis and exactly in line with or parallel to each other, the same result would be attained.

The following method was accordingly adopted. A plug of brass was inserted in the opening of each pivot, fitting tightly but without strain in the aperture. The pivots are of solid steel 3 in. in diameter and perforated by holes 1·75 in. in diameter. In each plug was firmly fixed a very carefully turned pin of hardened steel of about 1 mm. diameter. The block A and pin p of Hamy's method were of course discarded, and instead a small bracket was attached to the lever L carrying at its extremity a knife-edge of hardened steel which rested on the pin.

The arrangement of the apparatus as finally employed is shown in fig. 3, Plate 2. For the purpose of this illustration the instrument was mounted on a wooden frame carrying a wooden model of the pivot, as it was found impossible to photograph the whole apparatus *in situ*.

In Monsieur Hamy's method only the vertical movement of the pivot is considered, but for evaluating the pivot errors the horizontal displacements are of equal importance. For observing these a crank-lever, of the form shown in fig. 4, was pivoted on a fixed centre vertically above the pin. The arms of this lever were perpendicular to each other, and each carried a hardened steel straight-edge, of which one, the vertical, bore against the pin, whilst the other, the horizontal, supported the knife-edge and lever L. These two straight-edges were set accurately at right angles to each other, and so that, if produced, the straight lines which they determine would intersect at the centre on which the lever turns. They were also graduated so that the knife-edge of the lever L could be set at exactly the same distance from the centre as the pin. Any small horizontal displacement of the latter was thus converted into an equal vertical movement of the lever L, and could be observed in the same way as the vertical movements.

t was essential to keep the lever L sensibly horizontal in periments a shorter knife edge was necessary when this ver was in action. For convenience the two knife-edges were opposite sides of the main lever, so that in passing from

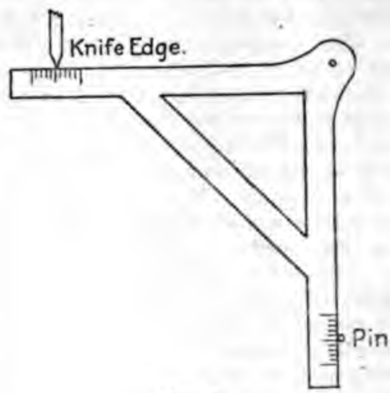
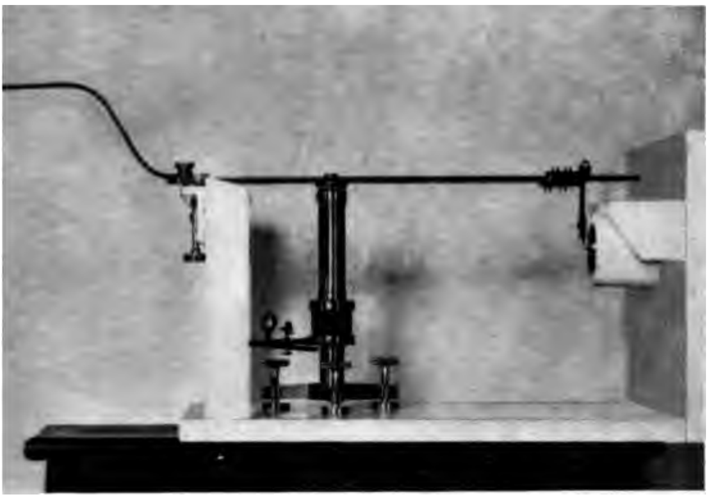
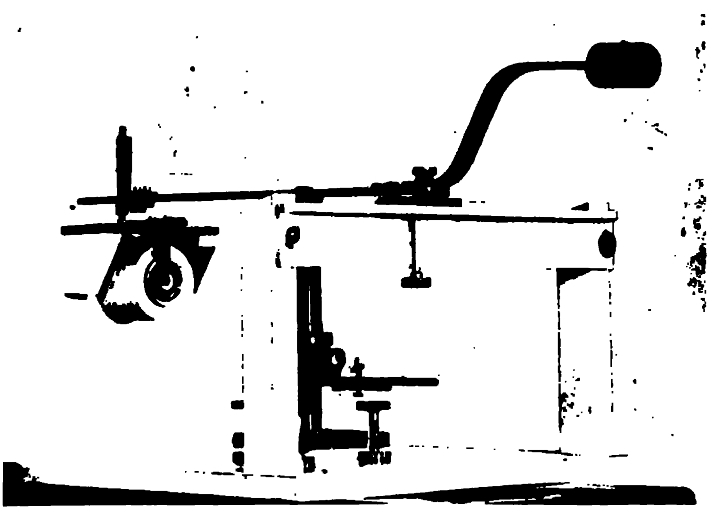


Fig. 4.

ions of the horizontal to observations of the vertical move-



IG. 3.—APPARATUS AS ARRANGED FOR THE VERTICAL CO-ORDINATE.



. 5.—APPARATUS AS ARRANGED FOR THE HORIZONTAL CO-ORDINATE.

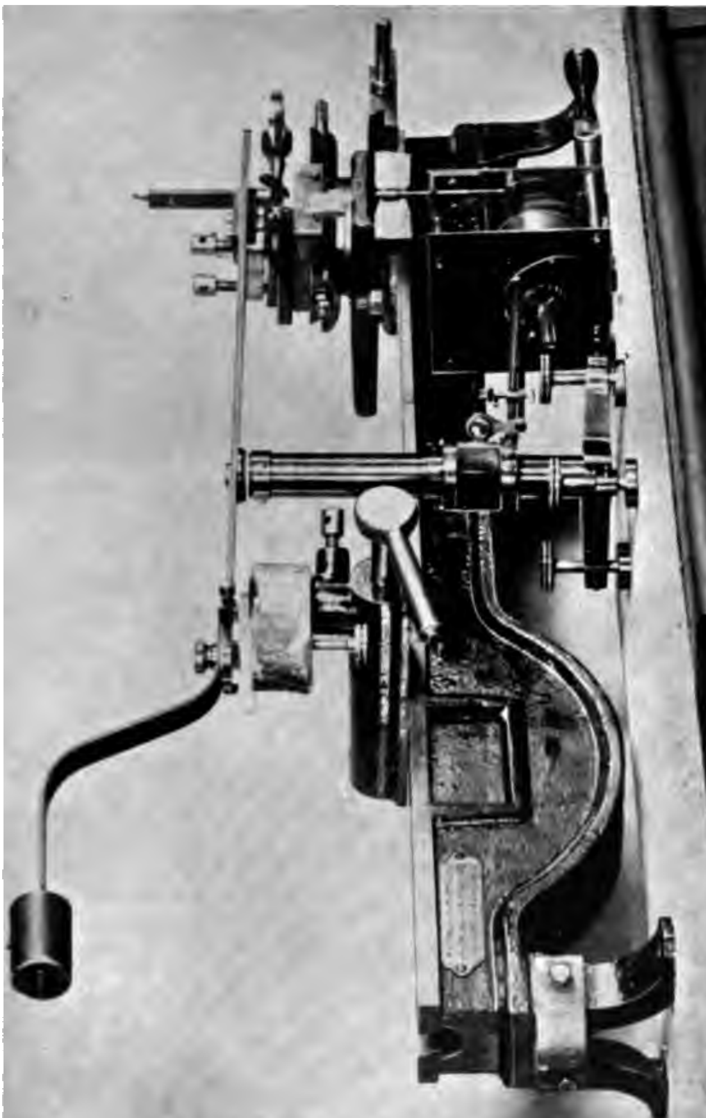


Fig. 6.—Arrangement for examination of the pins.

(2) *Effect of an inclination of the pin to the axis of the telescope.*—Since the movements of *any* two points, one in each pivot, will afford us the material for determining the pivot errors (see p. 316 of the memoir by Villarceau referred to above) it is clear that a mere eccentricity in the position of the pin can

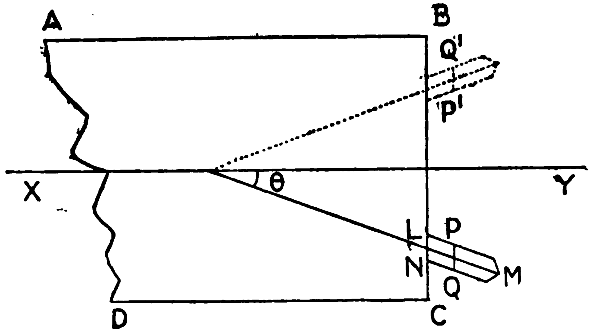


FIG. 8.

have no effect on the result. Let us next consider the effect of an inclination of the axis of the pin to the axis of rotation of the telescope. Let ABCD (fig. 8) represent one of the pivots, XY the line joining the centres of the two pivots, LMN a pin whose axis makes an angle θ with XY. Then if the knife-edge initially bears on the pin at P, it will, as the whole system rotates around XY, trace on the pin the section PQ, bearing at Q when the telescope has turned through 180° and the pin taken up the position P′Q′. This section PQ will, of course, be an ellipse, and

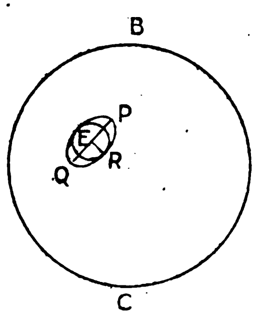


FIG. 9.

the movement of the lever will be exactly the same as if a cylindrical pin of elliptical section equal to PQ, but with axis parallel to XY, were substituted for the actual pin.

Now let BC, fig. 9, represent the end of the pivot, PRQ the elliptic section of the pin, and E the centre of this ellipse. The

greatest errors affecting our results occur at the points P and Q, and in linear measure they amount to EP—ER. But EP =ER sec θ; therefore the greatest error introduced by the inclination of the pin at an angle θ to the axis is

$$\mathrm{ER}\,(\sec\theta - 1).$$

But since θ will always be a small angle we may write this

$$\tfrac{1}{2}\,\mathrm{ER}\,.\,\theta^2.$$

We can easily ensure that θ shall not exceed 0·01. Hence we find

$$\tfrac{1}{2}\,\mathrm{ER}\,.\,\theta^2 = 0{\cdot}00005\,.\,\mathrm{ER}.$$

Since the pins employed are about a millimetre in diameter, or ER=0·5 mm., we find that the greatest possible error in the height of the knife-edge arising from the inclination of the pin cannot exceed

$$\overset{\mathrm{mm}}{0{\cdot}000025},$$

a quantity which we can afford to neglect.

The observations of pivot errors required the co-operation of two persons. One sat opposite the collimator and counted the fringes aloud, his whole attention being required for this. The other stood at the setting circle and rotated the telescope. The observations were made by Messrs. McClellan, Robinson, Wickham, and myself in about the proportion of 8, 1, 8 and 9 respectively. Starting from the setting 180° N.P.D., the innermost fringe was numbered 100 (to avoid negative numbers). The first fresh fringe appearing inside this was reckoned 101, the next 102, and so on. On the other hand, if the initially innermost fringe disappeared, the fringe taking its place was numbered 99. If it in turn vanished, the next outside it on assuming the position of innermost fringe was numbered 98, and so on. No attempt was made to subdivide the interval between two fringes. A change of one fringe represents a movement of half a wave-length of sodium light in the height of the black glass mirror, which corresponds to rather less than $0^{s}{\cdot}01$ in the time of transit of a star at the equator. At every fifth degree of N.P.D. the telescope was brought to rest, and the number of the fringe then innermost was entered. In this way, when all was going well, the displacements of one pivot in either coordinate could be investigated for a complete revolution of the telescope within a quarter of an hour without difficulty.

It should be stated that the light was obtained from an ordinary incandescent gas burner from which the mantle had been removed, and which was provided with a small platinum cup containing borax. In this way a very steady sodium flame was easily and cheaply obtained. In order to prevent any heating effects, a large sheet of glass was inserted between

the lamp and the apparatus, and for a similar reason the instrument was shielded from the heat of the observer's body by a large sheet of cardboard through a hole in which the observations were made.

The telescope was turned in both directions, but the change from one direction to another was not made until a series of observations was completed, and both coordinates of one pivot were always observed before changing the apparatus over to the other. That is to say the observations always took place in some such order as the following:—

$$\left.\begin{array}{l}\text{Direct} \ \ldots \begin{cases}\text{East}\begin{cases}\text{Horizontal}\\ \text{Vertical}\end{cases}\\ \text{West}\begin{cases}\text{Vertical}\\ \text{Horizontal}\end{cases}\end{cases}\\ \text{Retrograde}\begin{cases}\text{West}\begin{cases}\text{Horizontal}\\ \text{Vertical}\end{cases}\\ \text{East}\begin{cases}\text{Vertical}\\ \text{Horizontal}\end{cases}\end{cases}\end{array}\right\}\text{or}\left\{\begin{array}{l}\text{Retrograde}\begin{cases}\text{West}\begin{cases}\text{Vertical}\\ \text{Horizontal}\end{cases}\\ \text{East}\begin{cases}\text{Horizontal}\\ \text{Vertical}\end{cases}\end{cases}\\ \text{Direct} \ \ldots \begin{cases}\text{East}\begin{cases}\text{Vertical}\\ \text{Horizontal}\end{cases}\\ \text{West}\begin{cases}\text{Horizontal}\\ \text{Vertical}\end{cases}\end{cases}\end{array}\right.$$

In this way a complete direct or complete retrograde series could be obtained within a couple of hours under practically identical conditions as to temperature. Notwithstanding these precautions, however, it was sometimes found that, when the telescope had been turned right round through 360° the count of fringes did not return exactly to 100. This seemed to be due either to temperature changes, or to some slight settling down of the instrument, most probably the latter, as it did not usually occur in the first set of observations in the morning when they were made without disturbing the instrument from the position it had occupied during the night. A somewhat similar effect is referred to in Villarceau's memoir where he says (p. 323): "Lors des observations de la fin de mars et du commencement d'avril 1860 les cinq valeurs des coordonnées obtenues pour la hauteur zéro ont présenté une marche évidemment progressive ; on en a alors déduit de petites corrections qui ont été appliquées aux mesures, afin de les ramener à la simultanéité."

To whatever cause this discrepancy may have been due (and I am inclined to attribute it chiefly to a sagging of the lever) the change seems to have taken place very nearly proportionately to the time, as is shown by the remarkably close agreement between the direct and retrograde results when corrections are applied on this hypothesis, and in the mean the effect will practically disappear.

On the other hand, the effect of personality on the part of the observer in making these observations is practically zero. There can be no doubt about the appearance or disappearance of a fresh fringe, and it was only when vibrations due to wind or heavy traffic made the fringes tremulous that the least

uncertainty arose. When this occurred the observations were rejected.

In order to test this point Mr. McClellan and I made two independent series of observations of all four coordinates. The observations were arranged as follows. First, I observed at the collimator the vertical coordinates of the east pivot, the telescope being moved first in one direction and then in the other, whilst Mr. McClellan rotated the telescope and entered the observations at every fifth degree. In Table I., column 2, are given the sums of the numbers observed by me in the two directions of rotation for every tenth degree, the intermediate observations being omitted for economy of space. Then we changed places, Mr. McClellan observing at the collimator whilst I rotated the telescope. The sums of the direct and retrograde observations made by him are entered in a similar manner in the third column of the table. The horizontal coordinate was then observed by each of us independently, the results being entered in the fourth and fifth columns of the table; and similarly for the horizontal and vertical coordinates of the western pivot. These observations were made with two untested pins, of which one was afterwards found to be very irregular, and were subsequently rejected in deducing the errors of the pivots; but their value for testing the effect of personality is not depreciated by defectiveness of the pins. At the foot of the table are given the total range and the greatest differences between the figures in the corresponding series; and, bearing in mind that a unit in these sums corresponds to a movement of the black glass mirror through a quarter of a wave-length of sodium light, I think it will be admitted that the agreement of the two series is very remarkable.

Table I.

	East				West			
Z.D.	Vertical.		Horizontal.		Horizontal.		Vertical.	
	A.A.R.	C.	A.A.R.	C.	A.A.R.	C.	A.A.R.	C.
0°	200	200	200	200	200	200	200	200
10	182	182	201	202	185	186	200	201
20	173	174	197	198	170	171	206	207
30	171	172	191	191	158	159	210	211
40	177	178	181	182	146	147	214	215
50	185	187	171	172	137	137	218	219
60	185	186	163	162	132	133	218	219
70	186	188	154	154	130	131	215	217
80	184	185	147	146	128	128	191	192
90	166	167	129	128	121	121	163	166
100	153	154	123	123	110	110	138	140
110	149	149	123	123	102	103	120	123
120	153	155	123	123	98	99	109	112

Z.D.	East Vertical. A.A.R.	O.	East Horizontal. A.A.R.	O.	West Horizontal. A.A.R.	O.	West Vertical. A.A.R.	O.
130°	168	171	126	124	97	98	101	103
140	188	190	128	127	96	97	95	98
150	203	206	124	123	96	97	93	96
160	221	224	118	116	100	101	93	95
170	236	238	112	111	117	117	85	88
180	243	247	108	106	135	137	75	78
190	241	242	107	105	151	153	58	61
200	240	240	106	104	163	165	48	51
210	244	244	108	106	176	178	46	49
220	254	256	112	109	189	191	50	53
230	268	269	117	116	201	204	57	61
240	276	277	129	126	210	212	65	67
250	284	285	145	143	216	218	74	77
260	289	290	160	157	220	222	89	92
270	288	289	170	169	225	228	104	107
280	279	280	174	174	235	237	113	116
290	269	270	178	178	245	246	127	129
300	264	266	182	180	250	252	143	145
310	263	263	185	183	250	251	161	162
320	262	262	188	187	247	249	180	180
330	252	252	190	190	242	243	191	192
340	240	240	187	186	236	238	201	202
350	225	225	188	187	218	219	201	201
360	200	200	200	200	200	200	200	200
Range	140	141	95	98	154	155	172	170
Greatest Difference	−4		+3		−3		−4	

We have seen that the effect of minute irregularities of the pins on the position of the mirror *m* does not exceed a single wave-length of sodium light. Still further, however, to reduce the possible effects of such inequalities, between each complete set of measures and the next the brass plugs carrying the pins were rotated in the pivots through a right angle. This rotation had the effect of throwing the minute errors of the pins on different parts of the pivots, and so tended to eliminate their influence from the final mean. It also introduced a new eccentricity in the position of the pin, so that the actually observed displacements were in any two cases of a totally different character. In fig. 10, Plate 4, are exhibited the horizontal displacements observed in two series of observations made on July 7

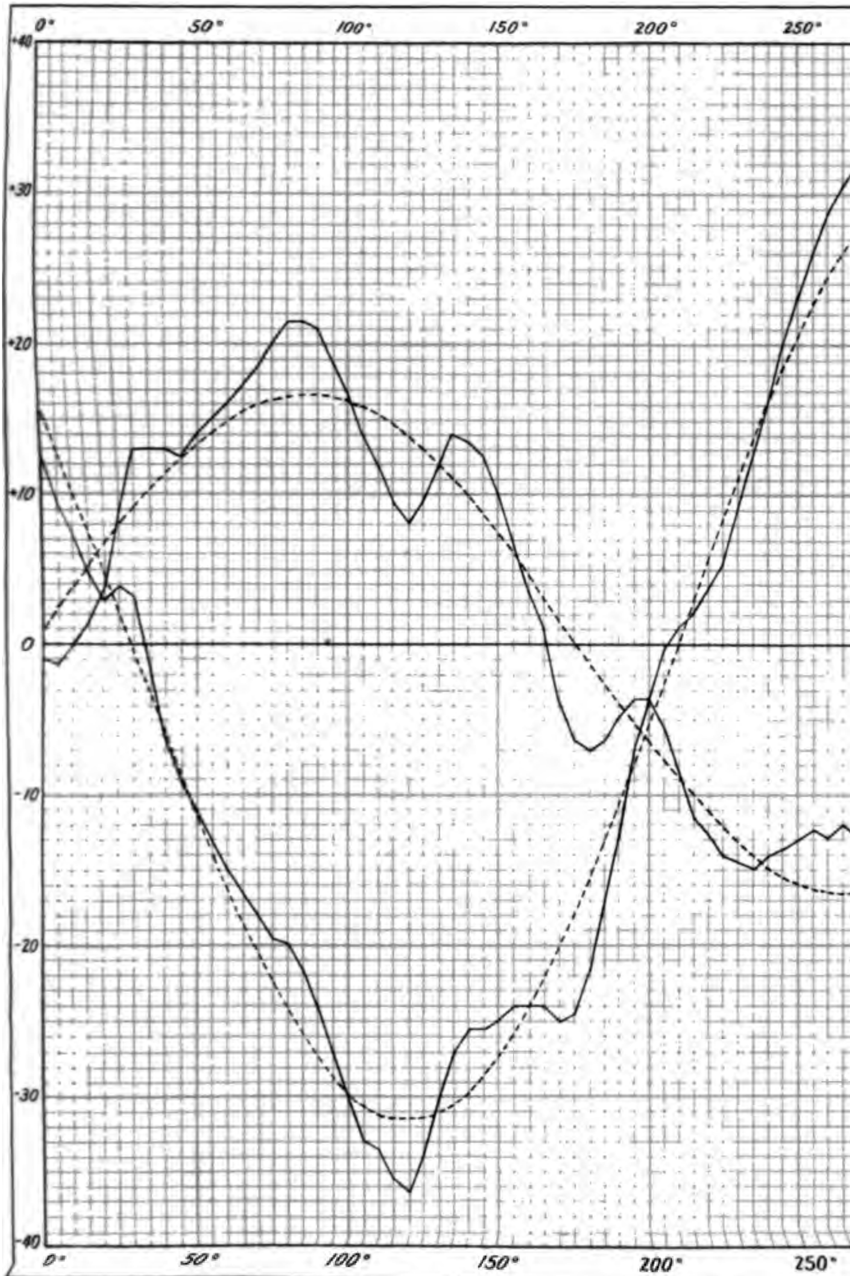


FIG. 10.—Observations of horizontal displacements, July 7

and July 12 respectively. In the figure the abscissæ represent the settings of the telescope in N.P.D., whilst the ordinates are the angular displacements of the axis of the telescope in a horizontal direction. In this diagram the side of one of the smaller squares represents a movement of $0''\cdot 13$. At first sight it might perhaps appear that these two traces are entirely different, but it must be remembered that each is a combination of the horizontal component of a circular movement due to the eccentricity of the pin and of the superimposed effect due to the irregularities of the pivots. If therefore we denote the horizontal component of the circular movement by x, the N.P.D. by Δ, and the pivot error by δx, each observation affords us an equation of the form

$$x+\delta x = a+b\cos(\Delta+C).$$

If now we determine the constants a, b, and C so as to satisfy the condition that $\Sigma(\delta x^2)$ shall be a minimum—*i.e.* if we attribute as much as possible of the observed displacements to the eccentric movement—it is easy to show, N being the number of observations made at equidistant settings of the circle, that

$$\tan C = -\frac{\Sigma(x\sin\Delta)}{\Sigma(x\cos\Delta)}$$

$$a = \frac{1}{N}\Sigma(x)$$

and

$$b = \frac{2}{N}\cdot\frac{\Sigma(x\cos\Delta)}{\cos C} = -\frac{2}{N}\cdot\frac{\Sigma(x\sin\Delta)}{\sin C}$$

In this way the dotted curves have been obtained, and the discrepancies between these and the observed results must be attributed to pivot errors. A remarkable agreement between the two apparently dissimilar series of observations will now become evident, and cannot fail to impress one with confidence in the accuracy of this method of determining these small and elusive irregularities.

The above comparison is given with the object of illustrating the character of the agreement between different series of observations; but in what follows, instead of keeping the horizontal and vertical components separate and calculating the effects of the pivot errors in azimuth and altitude, as is sometimes done, I have preferred to follow Villarceau in combining these into one single effect on the collimation, in virtue of which the latter can no longer be considered constant, but is affected with a variable term depending on the N.P.D. reading of the circle.

Referring to Villarceau's memoir, we find the equations for deducing the pivot errors as follows. The measured coordinates to any arbitrary origin of the centre of the pin on the eastern pivot being denoted by ξ and η, and those of the western pin by

ξ' and η' (ξ and ξ' being measured positively towards the south, η and η' positively towards the zenith), we take

$$x = \xi' - \xi \text{ and } y = \eta' - \eta.$$

Then, the observations being made at N different settings which divide exactly the circumference of the circle, we determine p and q from the equations

$$p = \frac{1}{N}\,\Sigma(x) \text{ and } q = \frac{1}{N}\,\Sigma(y).$$

If ζ denote the zenith distance, which is measured positively towards the south and continuously through 360°, and if R denote the length of the axis of the telescope between the measured points expressed in the same units as ξ, η, &c., we have N equations of the form

$$P = \{(x-p)\sin\zeta + (y-q)\cos\zeta\}/R\sin 1''.$$

We have next to take the mean, P_m, of all the separate values of P. Thus

$$P_m = \frac{1}{N}\,.\,\Sigma P\,;$$

and finally we have N equations of the form

$$\delta c = P - P_m$$

from which the separate values of δc are deduced, *i.e.* the variable part of the collimation depending on pivot errors.

The observations being expressed in "fringes," it is convenient to retain this unit throughout the computations, and to convert only the final results into angular measure. This is equivalent to neglecting the denominator, $R\sin 1''$, in the expression for P and calculating P, P_m, and δc in "fringes." To find the angular displacement of the axis corresponding to one of these units, we remark that one fringe takes the place of another when the distance between the upper surface of the collimator lens and the surface of the black glass mirror varies by half a wave-length, or when the difference in the lengths of the paths of the two interfering beams changes by a whole wave-length.

If, in fig. 2, a is the fulcrum of the lever, b the centre of the black glass mirror, and c the point on the lever directly above the knife-edge, the movement of b for a change of one fringe is half a wave-length ($\frac{1}{2}\lambda$); hence that of the knife-edge is $\frac{1}{2}\frac{ac}{ab}\,.\,\lambda$. Hence the factor required for reducing "fringes" to seconds of arc is

$$\mu = \frac{1}{2}\frac{ac}{ab}\,.\,\frac{\lambda}{R\sin 1''}.$$

[redacted]

From measures made on May 13 it was found that

$$R = \overset{mm}{1382{\cdot}7}\ ;\ ac = \overset{mm}{381{\cdot}7}\ ;\ \text{and}\ ab = \overset{mm}{128{\cdot}8}\ ;$$

and, since λ may be taken as equal to $\overset{mm}{0{\cdot}0005893}$, we find that

$$\mu = 0''{\cdot}1302.$$

With this factor the separate results and the mean values for δc corresponding to every fifth degree in the pointing of the telescope have been reduced, as given in Table II. The last column of this table accordingly exhibits the final results of this investigation with regard to the pivot errors of the Radcliffe Transit Circle.

TABLE II.

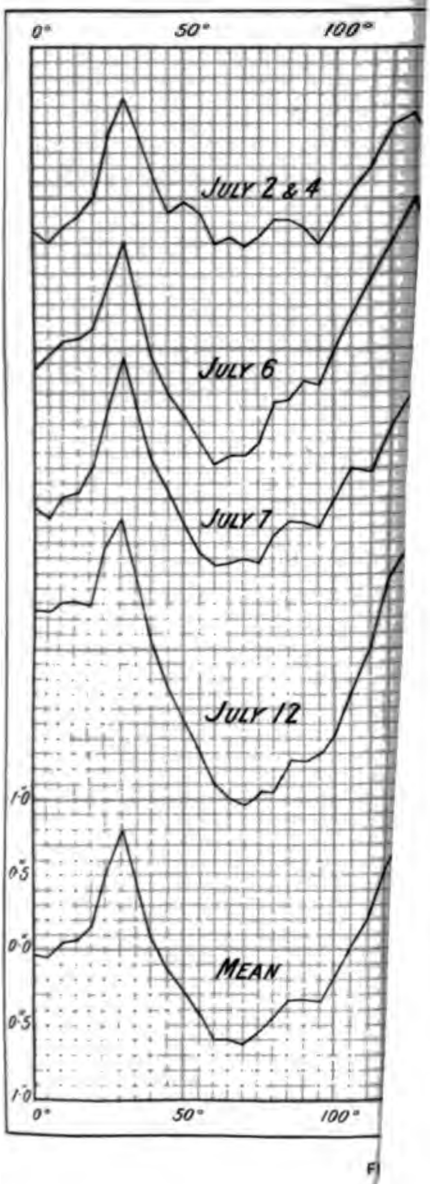
Values of δc.

N.P.D.	July 2 and 4.	July 6.	July 7.	July 12.	Mean.
°	″	″	″	″	″
0	−0·23	−0·16	−0·05	+0·24	−0·049
5	−0·29	−0·06	−0·13	+0·25	−0·058
10	−0·20	+0·03	0·00	+0·29	+0·029
15	−0·12	+0·06	+0·04	+0·31	+0·073
20	+0·03	+0·12	+0·19	+0·29	+0·156
25	+0·38	+0·40	+0·61	+0·66	+0·513
30	+0·66	+0·70	+0·95	+0·88	+0·796
35	+0·41	+0·31	+0·60	+0·47	+0·447
40	+0·13	−0·05	+0·25	+0·06	+0·097
45	−0·08	−0·31	+0·07	−0·26	−0·143
50	−0·05	−0·44	−0·15	−0·48	−0·281
55	−0·09	−0·61	−0·35	−0·69	−0·435
60	−0·27	−0·75	−0·45	−0·92	−0·596
65	−0·26	−0·71	−0·43	−0·99	−0·598
70	−0·32	−0·72	−0·40	−1·05	−0·622
75	−0·26	−0·64	−0·42	−0·95	−0·567
80	−0·14	−0·38	−0·25	−0·94	−0·429
85	−0·14	−0·35	−0·16	−0·75	−0·351
90	−0·19	−0·21	−0·17	−0·76	−0·333
95	−0·29	−0·23	−0·19	−0·69	−0·349
100	−0·14	−0·06	−0·01	−0·59	−0·200
105	+0·05	+0·23	+0·18	−0·31	+0·037
110	+0·19	+0·43	+0·16	−0·02	+0·190
115	+0·48	+0·70	+0·49	+0·45	+0·530
120	+0·57	+1·00	+0·69	+0·69	+0·738

[redacted]

ly 2 and 4.	July 6.	July 7.	July 12.	Mean.
+0″·34	+0″·44	+0″·34	+0″·38	+0″·374
−0·19	+0·07	−0·15	−0·06	−0·083
−0·60	−0·41	−0·46	−0·44	−0·478
−0·61	−0·35	−0·49	−0·45	−0·474
−0·33	−0·35	−0·27	−0·42	−0·344
−0·21	−0·14	−0·06	−0·21	−0·158
+0·09	+0·07	+0·12	+0·12	+0·101
+0·27	+0·15	+0·40	+0·44	+0·314
+0·39	+0·28	+0·60	+0·55	+0·455
+0·57	+0·32	+0·78	+0·72	+0·596
+0·66	+0·29	+0·82	+0·61	+0·593
+0·54	+0·29	+0·73	+0·58	+0·535
+0·35	+0·21	+0·55	+0·43	+0·385
+0·25	+0·09	+0·51	+0·36	+0·304
+0·23	+0·01	+0·38	+0·42	+0·257
+0·13	−0·07	+0·29	+0·21	+0·141
+0·07	−0·10	+0·12	+0·25	+0·088
+0·07	−0·16	+0·03	+0·22	+0·041
−0·07	−0·19	−0·19	+0·14	−0·078
−0·19	−0·30	−0·48	−0·13	−0·276
−0·30	−0·41	−0·82	−0·28	−0·452
−0·34	−0·27	−0·64	−0·18	−0·357
−0·13	−0·10	−0·61	+0·05	−0·197

[redacted]



F

P.D.	July 2 and 4.	July 6.	July 7.	July 12.
°	"	"	"	"
5	+0·34	+0·44	+0·34	+0·38
0	−0·19	+0·07	−0·15	−0·06
5	−0·60	−0·41	−0·46	−0·44
0	−0·61	−0·35	−0·49	−0·45
5	−0·33	−0·35	−0·27	−0·42
0	−0·21	−0·14	−0·06	−0·21
5	+0·09	+0·07	+0·12	+0·12
0	+0·27	+0·15	+0·40	+0·44
5	+0·39	+0·28	+0·60	+0·55
0	+0·57	+0·32	+0·78	+0·72
5	+0·66	+0·29	+0·82	+0·61
0	+0·54	+0·29	+0·73	+0·58
5	+0·35	+0·21	+0·55	+0·43
0	+0·25	+0·09	+0·51	+0·36
5	+0·23	+0·01	+0·38	+0·42
00	+0·13	−0·07	+0·29	+0·21
05	+0·07	−0·10	+0·12	+0·25

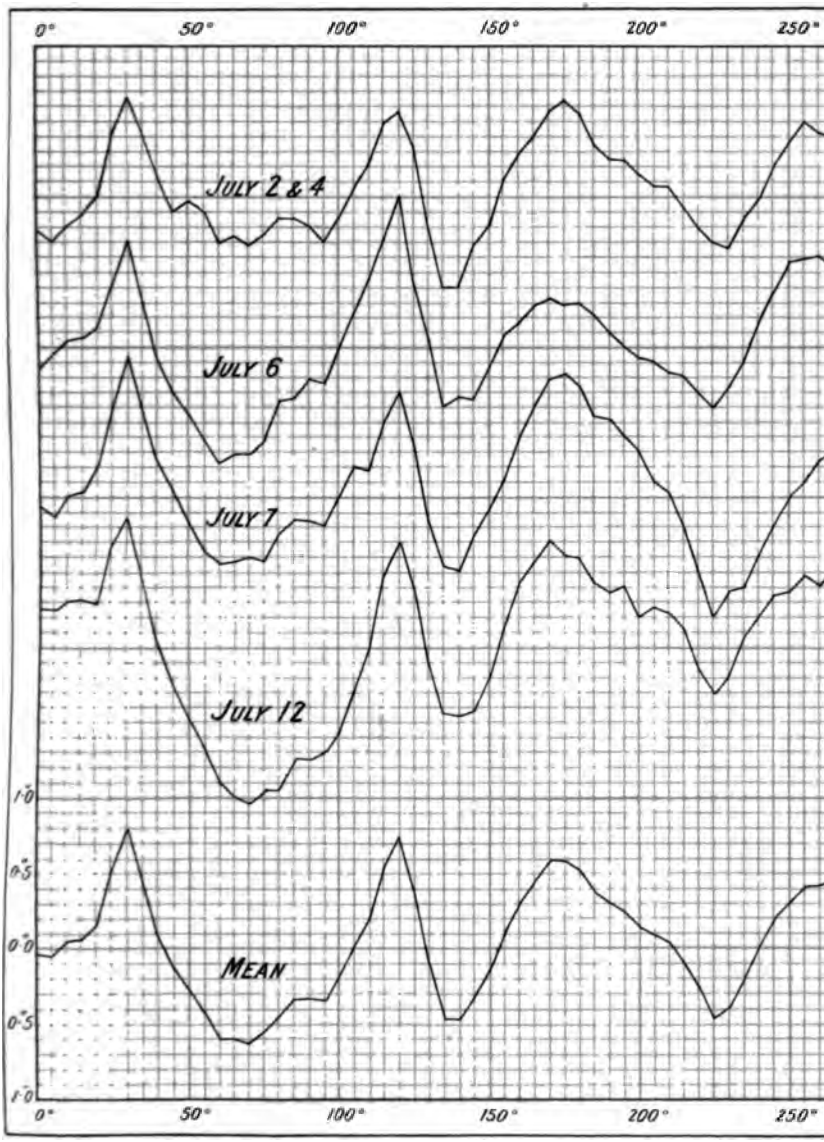


FIG. 11.—Pivot Errors of Radcliffe Transit Circle.

N.P.D.	July 2 and 4.	July 6.	July 7.	July 12.	Mean.
°	″	″	″	″	″
320	−0·29	−0·31	−0·18	−0·12	−0·221
325	−0·41	−0·23	−0·32	−0·13	−0·271
330	−0·53	−0·42	−0·46	−0·16	−0·393
335	−0·55	−0·39	−0·49	−0·23	−0·414
340	−0·52	−0·39	−0·49	−0·19	−0·398
345	−0·44	−0·40	−0·45	−0·17	−0·366
350	−0·36	−0·22	−0·24	−0·01	−0·210
355	−0·30	−0·15	−0·09	+0·09	−0·112
360	−0·23	−0·16	−0·05	+0·24	−0·049

In fig. 11, Plate 5, the separate results as given in this table have been plotted down, and the points of each series so obtained have been joined by straight lines. The means contained in the last column of the table have been treated in a similar manner, from which we obtain the fifth and lowest trace.

This diagram shows at a glance that, while there are differences between one set of observations and another, as is only to be expected when the minuteness of these quantities is borne in mind, yet the main features are repeated in a remarkable way in all four series of observations. In order, however, to form an estimate of the precision attaching to these results, I have taken the differences between each of the four individual results in Table II., and the mean, for each pointing of the telescope, and from the differences so obtained the probable error has been calculated in the usual way. I thus find that the probable error of a single determination is

$$\pm 0''\cdot 109,$$

and therefore the probable error of the means in the last column is

$$\pm 0''\cdot 054.$$

We have next to consider how these errors will affect the right ascension of a star as already computed from observations made with this instrument on the hypothesis of cylindrical pivots. For this purpose let us take

α, δ, and ζ to denote the R.A., Decl., and zenith distance of a star respectively;

t to denote the clock time of its transit across the middle wire;

dt to denote the correction to the clock;

κ to denote the constant of diurnal aberration ($0''\cdot 309 \cos \phi$);

a to denote the azimuth;

b „ „ level;

and c „ „ collimation.

Then equations (9) and (22) of Villarceau's memoir become

$$a = t + dt + \frac{1}{15 \cos \delta}\{\psi - \kappa\}$$

and
$$\psi = a \sin \zeta + b \cos \zeta + c + \delta c.$$

Since the head of the micrometer screw of the Radcliffe Transit Circle is on the west of the tube, not on the east, as in the case imagined by Villarceau, it will be necessary, as he points out, to change the sign of k (the value of a revolution of the screw) in his subsequent formulæ. Hence, adopting his notation, according to which

l denotes the reading for coincidence of the middle wire with its reflexion at the nadir;

m denotes the reading for coincidence of the middle wire with the wire of S. collimator;

n denotes the reading for coincidence of the middle wire with the wire of N. collimator;

and ν denotes the reading at which the reticule is set for observations of stars,

but putting

δc_1 for the value of δc when the telescope is pointing on S. collimator (*i.e.* $\zeta =$ *one* right angle);

δc_2 for the value of δc when the telescope is pointing on the nadir (*i.e.* $\zeta =$ *two* right angles);

and δc_3 for the value of δc when the telescope is pointing on N. collimator (*i.e.* $\zeta =$ *three* right angles),

then Villarceau's equations (23) and (26) become respectively

$$b = k(l - \nu) + c + \delta c_2$$

and
$$c = k\left(\nu - \frac{m+n}{2}\right) - \tfrac{1}{2}(\delta c_1 + \delta c_3).$$

Now if we take $\bar{c}$ as the value of the collimation deduced in the ordinary way, without regard to pivot errors, we have simply

$$\bar{c} = k\left(\nu - \frac{m+n}{2}\right) \text{ and } \therefore\ c = \bar{c} - \tfrac{1}{2}(\delta c_1 + \delta c_3).$$

Also since $k\nu = \bar{c} + k\,\dfrac{m+n}{2}$

$$\begin{aligned} \therefore\quad b &= k\left(l - \frac{m+n}{2}\right) + c - \bar{c} + \delta c_2 \\ &= k\left(l - \frac{m+n}{2}\right) + \delta c_2 - \tfrac{1}{2}(\delta c_1 + \delta c_3). \end{aligned}$$

But if the pivot errors are neglected, $k\left(l-\frac{m+n}{2}\right)$ is precisely the value we should find for the level constant. Hence, if this be denoted by $\bar{b}$ we have

$$\left.\begin{aligned} b &= \bar{b}+\delta c_2-\tfrac{1}{2}(\delta c_1+\delta c_3) = \bar{b}+\Delta b \\ \text{and} \qquad c &= \bar{c}-\tfrac{1}{2}(\delta c_1+\delta c_3) \qquad = \bar{c}+\Delta c \end{aligned}\right\} \quad \dots \quad \dots \quad (1)$$

in which Δb and Δc are *constant* quantities depending on the pivot errors, given by the equations

$$\left.\begin{aligned} \Delta c &= -\tfrac{1}{2}(\delta c_1+\delta c_3) \\ \text{and} \qquad \Delta b &= \Delta c+\delta c_2 \end{aligned}\right\} \quad \dots \quad \dots \quad \dots \quad (2)$$

We have next to determine the correction to the azimuth constant as obtained in the usual way by observations of stars, and the error committed in deducing the clock correction by the neglect of the pivot errors.

If for simplicity we denote the azimuth, level, and collimation factors by A, B, and C; that is to say, if we take

$$A = \frac{1}{15}\frac{\sin\zeta}{\cos\delta}\,;\ B = \frac{1}{15}\frac{\cos\zeta}{\cos\delta}\,;\ \text{and } C = \frac{1}{15}\frac{1}{\cos\delta}$$

then Villarceau's equations (9) and (22) give us for any star

$$\alpha = t+dt+\{a\,.\,A+b\,.\,B+(c+\delta c-\kappa)\,.\,C\}$$

substituting from equations (1) above

$$\alpha = \{t+\bar{b}\,.\,B+(\bar{c}-\kappa)C\}+dt+\{aA+\Delta b\,.\,B+(\Delta c+\delta c)\,.\,C\}$$

If now we take

$$\tau = t+\bar{b}\,.\,B+(\bar{c}-\kappa)C$$

where τ is the time of transit corrected in the ordinary way for level, collimation, and diurnal aberration, but without regard to pivot errors, we have

$$\alpha = \tau+dt+a\,.\,A+\{\Delta b\,.\,B+(\Delta c+\delta c)\,.\,C\}$$

Now Δb and Δc being constants, and δc as well as the factors B and C depending only on the position of the star, the last term in this may be tabulated with N.P.D. as argument. If we denote this quantity by Q, we have simply

$$\alpha = \tau+dt+aA+Q \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

In general the azimuth constant is determined by comparing the observation of a star which culminates south of the zenith with that of a close polar star at upper or lower culmination. For the former we have

$$\alpha = \tau+dt+a\,.\,A+Q$$

larly for the polar star

$$a' = \tau' + dt + a \, . \, A' + Q'$$

s is sometimes the case, the azimuth has been deduced nsits of two close polars, one above and the other below or from two transits of the same star at an interval of ours, the first equation will apply to one, the second to the other transit. Thus in any case we have

$$a - a' = \tau - \tau' + a(A - A') + Q - Q'$$

$$a = \frac{(a - a') - (\tau - \tau')}{A - A'} - \frac{Q - Q'}{A - A'}.$$

$\frac{a') - (\tau - \tau')}{A - A'}$ is the value of the azimuth constant deter- the usual way on the assumption of cylindrical pivots. note it by $\bar{a}$ we have

$$a = \bar{a} + \Delta a$$

$$\Delta a = -\frac{Q - Q'}{A - A'} \quad \dots \quad \dots \quad \dots \quad (4)$$

where $\bar{a}$ is the value of the star's right ascension deduced without regard to pivot errors. If, further, we write $a = \bar{a} + \Delta a$, we have as the correction necessary to the already determined R.A.

$$\Delta a = \Delta a_{\cdot} \left(A - \frac{\Sigma A}{n}\right) + \left(Q - \frac{\Sigma Q}{n}\right) \quad \dots \quad \dots \quad (5)$$

We thus see that for new observations the correction for pivot errors may be taken from Table II., where it appears as a correction to the collimation constant depending upon the star's N.P.D., combined with the constant corrections Δb and Δc from equations (2) affecting the level and collimation constants respectively. When these corrections are applied the clock and azimuth errors deduced in the ordinary way will not be affected by the pivot errors. If, however, we seek the total correction to the already computed R.A. of a star it will be necessary to compute the quantities $Q = \Delta b \,.\, B + (\Delta c + \delta c) \,.\, C$. With these quantities we must determine Δa by means of equation (4), and finally Δa by means of equation (5).

To be rigorously exact it would be necessary to compute Δa, and hence Δa, for every separate night of observation. Fortunately, however, it is found that the corrections so computed from night to night vary so slightly that a constant correction may with sensible accuracy be taken as applicable to any particular star.

From the values of δc given in Table II. we find by interpolation

$$\delta c_1 = +0''{\cdot}044\,;\ \delta c_2 = -0''{\cdot}204\,;\ \text{and}\ \delta c_3 = -0''{\cdot}072$$

Therefore

$$\Delta c = +0''{\cdot}014 \text{ and } \Delta b = -0''{\cdot}190.$$

We thus obtain the following table for Q :—

TABLE III.

Values of $Q = \Delta b \,.\, B + (\Delta c + \delta c) \,.\, C$.

N.P.D.	Q	N.P.D.	Q	N.P.D.	Q	N.P.D.	Q
°	s	°	s	°	s	°	s
		−5	+0·181	+10	−0·047	+70	−0·054
−50	+0·008	4	·212	15	·023	75	·048
45	·017	3	·265	20	−0·002	80	·038
40	·026	2	·374	25	+0·054	85	·032
35	·036	−1	+0·719	30	·083	90	·029
30	·059	0		35	+0·031	95	·029
25	·076	+1	−0·716	40	−0·008	100	·019
20	·094	2	·367	45	·030	105	−0·001
15	·119	3	·254	50	·039	110	+0·010
−10	·123	4	·196	55	·049	115	·037
		+5	·156	60	·059	120	·056
				+65	·056	125	+0·030
						+130	−0·006

[redacted] these values the correction to the azimuth constant Δa
[redacted] computed from equation (4) for any pair of stars whose
[redacted] are found, one in the top row and the other in the left-
[redacted] of Table IV. Thus, if the azimuth had been com-
[redacted] a star of -2° N.P.D. and another of $+90^\circ$ N.P.D.
[redacted] of Δa would be $-0''\cdot34$. Seeing that all the polar
[redacted] have been used at Oxford for azimuth are situated
[redacted] than 4° of the pole, and that the part of the correction
[redacted] depends on Δa, does not amount to $0^s\cdot1$ even at 10°
[redacted] and is less than $0^s\cdot02$ from the zenith to the southern
[redacted] we see from the small differences in Table IV. that it
[redacted] sufficient to take a mean value of $-0''\cdot33$ as being the
[redacted] to the azimuth constant however determined.

TABLE IV.

Values of Δa.

[redacted]	+1°.	+2°.	+3°.	+4°.	+50°.	+70°.	+90°.	+110°.
[redacted]	″	″	″	″	″	″	″	″
[redacted]	−0·30	−0·31	−0·31	−0·31	−0·32	−0·33	−0·32	−0·30
[redacted]	−0·31	−0·31	−0·32	−0·32	−0·34	−0·36	−0·34	−0·31
[redacted]	−0·31	−0·32	−0·33	−0·33	−0·37	−0·40	−0·37	−0·33
[redacted]	−0·31	−0·34	−0·34	−0·35	−0·40	−0·45	−0·41	−0·35
[redacted]	−0·29	−0·29	−0·29	−0·28				
[redacted]	−0·28	−0·26	−0·25	−0·24				

[redacted]

TABLE V.

Corrections for Irregularities of the Pivots to be applied to all Right Ascensions of Stars observed with the Transit Circle of the Radcliffe Observatory.

N.P.D.	Δα.	N.P.D.	Δα.	N.P.D.	Δα.	N.P.D.	Δα.
°	s	°	s	°	s	°	s
		−5	+0·057	+10	+0·062	+70	−0·018
−50	+0·028	4	·049	15	·060	75	·013
45	·034	3	·036	20	·067	80	−0·004
40	·041	2	+0·015	25	·115	85	+0·001
35	·048	−1	−0·030	30	·138	90	·002
30	·067	0		35	·082	95	·001
25	·078	+1	+0·095	40	·040	100	·010
20	·088	2	·054	45	·015	105	·027
15	·099	3	·037	50	+0·004	110	·036
−10	+0·076	4	·030	55	−0·008	115	·062
		+5	+0·031	60	·020	120	·079
				+65	−0·018	125	·052
						+130	+0·014

These are the corrections to be applied to all the right ascensions of the Radcliffe Catalogue for 1890 to free them from the effect of the irregularities of the pivots. Since the publication of that work a large number of right ascensions have been observed with the same instrument. These observations, which are now in preparation for the press, have been corrected by the application of the above quantities, and should be entirely free from the effect of pivot error.

As I have pointed out at the beginning of this paper, it was the existence of small but systematic differences between the right ascensions observed at Oxford and those observed with the Cape and Greenwich Transit Circles which in the first instance directed special attention to the form of the pivots of the Radcliffe instrument and gave rise to the present inquiry. It will be of interest therefore to compare these systematic differences with the corrections for pivot errors now deduced in a wholly independent manner. For this purpose I have given in Table VI. below the differences in R.A. multiplied by sin N.P.D., as found by Stone, between the Radcliffe Catalogue for 1890, and each of the two catalogues, Stone 1880, and Greenwich 1880, reprinted from his paper in the *Monthly Notices*, vol. lv. p. 295. In the last column I have added the corrections for pivot errors, also multiplied by sin N.P.D.

Table VI.

Group.	Mean N.P.D. of Group.	Differences in R.A. × sin N.P.D. Rad.—Stone.	Wt.	Rad.—Grn.	Wt.	Corrections for Pivot Errors.
° °	° ′	s		s		s
0 - 5				+0·014	636	+0·002
5 - 10				+0·024	17	+0·006
10 - 15				−0·017	54	+0·014
15 - 20				−0·014	71	+0·019
20 - 25				−0·017	64	+0·036
25 - 30				−0·002	62	+0·059
30 - 38½				−0·005	55	+0·039
38½ - 45	42 0	+0·015	4	+0·001	67	+0·020
45 - 50	46 0	+0·050	5	+0·027	44	+0·010
50 - 55	52 0	+0·045	11	+0·014	74	−0·001
55 - 60	57 30	+0·042	22	+0·031	69	−0·022
60 - 65	62 0	+0·056	118	+0·040	229	−0·017
65 - 70	68 0	+0·041	130	+0·036	296	−0·017
70 - 75	72 30	+0·057	151	+0·043	346	−0·015
75 - 80	77 30	+0·037	233	+0·038	405	−0·009
80 - 85	82 30	+0·034	293	+0·034	482	−0·002
85 - 90	87 30	+0·036	181	+0·028	352	+0·002
90 - 95	92 30	+0·017	397	+0·014	600	+0·002
95 - 100	97 30	−0·004	352	−0·017	617	+0·006
100 - 105	102 30	−0·021	259	−0·040	495	+0·018
105 - 110	107 30	−0·024	277	−0·051	606	+0·030
110 - 115	112 30	−0·053	642	−0·078	368	+0·045
115 - 120	117 30	−0·064	303	−0·091	195	+0·062
120 - 125½	122 30	−0·133	145	−0·158	45	+0·056

It will be seen from this table that in almost every case where the correction for pivot error amounts to as much as $0^s{\cdot}01$ it is of opposite sign to the corresponding difference of R.A. North of the zenith the correction is too big and more than cancels these differences, whilst on the other side of the zenith, and down to about 5° south of the equator, the correction is too small. From N.P.D. 95° down to 120° the corrections almost exactly account for the marked differences between the Radcliffe 1890 and Stone 1880, whilst the differences Radcliffe–Greenwich are largely reduced. The relatively large difference for the last group is, however, only very partially accounted for by pivot errors, and must be due to a combination of causes, one of which is obviously the very low altitude of these stars at Oxford and Greenwich.

Addendum.—Since the above was written I have received Professor Auwers' *Tafeln zur Reduction von Stern-Catalogen auf das System des Fundamentalcatalogs des Berliner Jahrbuchs.* From the comparison given in Table VII. it will be seen that the corrections depending on declination, $\Delta\alpha_\delta$, which he finds to be necessary to reduce the Oxford right ascensions to his system are, to a great extent, accounted for by the pivot errors as determined in this paper.

TABLE VII.

N.P.D.	Red. to Fund. Cat.	Corr. for Pivot Error.	N.P.D.	Red. to Fund. Cat.	Corr. for Pivot Error.
°	°	s	°	s	s
10	+0·125	+0·062	70	−0·003	−0·018
15	+0·113	+0·060	75	0·000	−0·013
20	+0·095	+0·067	80	+0·005	−0·004
25	+0·075	+0·115	85	+0·014	+0·001
30	+0·056	+0·138	90	+0·026	+0·002
35	+0·040	+0·082	95	+0·041	+0·001
40	+0·027	+0·040	100	+0·062	+0·010
45	+0·018	+0·015	105	+0·084	+0·027
50	+0·009	+0·004	110	+0·101	+0·036
55	+0·002	−0·008	115	+0·120	+0·062
60	−0·001	−0·020	120	+0·137	+0·079
65	−0·003	−0·018			

The Positions of Seventy Stars in the Cluster M 13 Herculis. By H. C. Plummer, M.A.

The complete investigation, so far as it can be made by photographic means, of a dense cluster, such as *M* 13 *Herculis*, must naturally be based on plates taken with a telescope of great focal length and high resolving power. To secure such plates is in fact one of the important functions of the very largest refractors. But the large-scale photographs thus obtained may cover so small a region of the sky that they contain no stars whose meridian places are known and by which the reduction of the plates can therefore be made. In this case it is necessary to determine the positions of a sufficient number of reference stars by some auxiliary means. This has been done for the cluster mentioned at the request of the director of the Liverpool Observatory, who is at present discussing a photograph taken with the Yerkes refractor.

The Oxford plate (No. 2372) was taken with the astrographic instrument on 1904 September 17. An exposure of eighty

e knotty globular patches, as if the meteor in its flight
 occasional larger masses of incandescent matter.
trail was tubular or consisted of two parallel narrow
each component being about twice the angular diameter
er, or about 90″ in width, separated by an interval of
. The trail remained feebly visible to the naked eye for
nutes, but telescopic observation showed it to be diffusing
ulous patches, with sufficient luminosity to render comet-
futile from the time of first observation, 11.39 P.M., until
.

position of the telescope at the time of appearance was
45^m, Dec. $+28°$. Approximate position of trail was from
° to $+35°$, in a circle of R.A. at $0^h\ 45^m$.

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meris for Physical Observations of the Moon for 1905.

By A. C. D. Crommelin.

Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Physical Libration. Long.	Physical Libration. Lat.	C.

Lund A.G.C.	x.	y.	Δα.	Δδ.
			s	"
6836	8·2174	13·2583	+0·05	−1·1
6838	8·4315	1·5274	+0·03	+0·9
6840	9·2697	25·5471	−0·09	0·0
6844	9·9932	23·6048	−0·10	0·0
6846	10·2429	19·7579	+0·08	+0·2
6848	10·5654	3·4090	−0·14	+0·1
6850	11·7567	9·7306	+0·02	−1·1
6851	12·0784	19·0228	+0·02	−0·3
6857	14·5183	8·3966	+0·11	+0·3
6863	16·6194	13·3717	+0·02	−0·7
6864	17·1310	19·8546	+0·08	+0·1
6865	18·0451	11·8143	−0·04	−0·5
6867	19·9075	23·7595	+0·12	−0·1
6868	20·1430	10·3230	−0·02	−0·6
6869	20·7402	4·0765	−0·07	+1·2
6870	20·8000	4·6149	+0·03	−0·4
6876	22·8420	20·2366	+0·01	−1·7
6878	23·1917	2·7869	+0·08	+1·6
6880	23·3958	16·2414	−0·10	+1·2
6882	24·2654	15·5270	+0·03	−0·8
6883	24·1711	23·4301	−0·20	−1·0
6884	24·7864	6·9385	−0·03	−0·6
6885	24·9923	16·3677	−0·15	−0·3
6886	24·9972	19·1082	+0·12	+2·5

Table II.

Ref. No.	1900·0. x.	1900·0. y.	1900·0. R.A.	1900·0. Decl.
	′	′	h m s	° ′ ″
1	− 6·958	−0·408	16 37 25·30	+36 39 35·2
2	− 5·696	−3·998	37 31·62	36 53·9
3	− 5·620	+5·046	37 31·94	45 2·6
4	− 5·582	−0·249	37 32·16	39 44·9
5	− 5·258	+1·605	37 33·77	41 36·1
6	− 4·805	+6·881	37 36·08	33 7·0
7	− 3·920	+4·878	37 40·43	44 52·6
8	− 3·874	+5·217	37 40·70	34 46·9
9	− 3·811	+0·907	37 40·99	40 54·3
10	− 3·594	+8·882	16 37 42·11	+36 31 7·0

1900·0. x.	1900·0. y.	1900·0. R.A.	1900·0. Decl.
′	′	h m s	° ′ ″
− 3·474	− 2·694	16 37 42·69	+ 36 37 18·3
− 3·031	− 7·248	37 44·91	32 45·1
− 2·974	− 1·907	37 45·18	38 5·5
− 2·944	− 3·865	37 45·33	36 8·0
− 2·926	+ 2·591	37 45·40	42 35·4
− 2·652	− 0·534	37 46·78	39 27·9
− 2·117	+ 1·760	37 49·44	41 45·6
− 2·073	− 3·000	37 49·67	37 0·0
− 1·957	− 2·753	37 50·25	37 14·8
− 1·663	− 9·208	37 51·72	30 47·5
− 1·652	− 5·678	37 51·77	34 19·3
− 1·436	− 0·520	37 52·84	39 28·8
− 1·346	+ 5·422	37 53·28	45 25·3
− 1·266	− 3·060	37 53·69	36 56·4
− 0·866	+ 3·400	37 55·68	43 24·0

Ref. No.	1900·0. x.	1900·0. y.	1900·0. R.A.	1900·0. Decl.
	′	′	h m s	° ′ ″
46	+ 2·550	−2·607	16 38 12·71	+36 37 23·5
47	+ 2·654	−0·090	38 13·24	39 54·5
48	+ 3·186	−4·306	38 15·87	35 41·6
49	+ 3·196	−4·881	38 15·92	35 7·1
50	+ 3·228	+1·140	38 16·10	41 8·3
51	+ 3·352	+4·739	38 16·73	44 44·3
52	+ 3·360	+0·332	38 16·76	40 19·9
53	+ 3·572	−2·096	38 17·80	37 54·2
54	+ 3·576	−5·911	38 17·81	34 5·3
55	+ 4·092	−1·206	38 20·40	38 47·5
56	+ 4·228	+0·438	38 21·08	40 26·2
57	+ 4·315	+4·864	38 21·54	44 51·7
58	+ 4·504	+1·461	38 22·47	41 27·5
59	+ 4·620	−3·228	38 23·02	36 46·2
60	+ 4·636	+5·332	38 23·14	45 19·8
61	+ 5·045	−0·819	38 25·15	39 10·7
62	+ 5·308	−5·020	38 26·44	34 58·7
63	+ 5·624	+3·228	38 28·06	43 13·5
64	+ 6·722	+1·002	38 33·53	40 59·8
65	+ 7·110	−6·172	38 35·41	33 49·4
66	+ 8·166	−1·300	38 40·71	38 41·6
67	+ 8·222	−0·669	38 41·00	39 19·4
68	+ 8·468	−3·642	38 42·20	36 21·0
69	+ 8·900	+0·666	38 44·39	40 39·4
70	+ 10·003	−0·938	16 38 49·88	36 39 3·1

University Observatory, Oxford:
1904 *November* 8.

Note on the Variation of ε Aurigæ. By Colonel E. E. Markwick.

Dr. Ludendorff, of Potsdam, has recently published a paper on the variability of *ε Aurigæ*, in which he reaches some rather remarkable conclusions. Having discussed a considerable number of observations of the brightness of this star made by observers of repute, commencing with those of Argelander in 1842, he

at the light-variation is of the Algol-type. The extra-
part of the result is the great length of the period—
rs. Minima occur, or follow one another, after 9905^d,
years. As they are possibly unequal in brightness, it is
ed they represent the passing of the lesser star between
he primary, followed by a passing of the same behind or
r side of the primary. The duration of the light change
ears, divided symmetrically as follows :—

	d.
m cessation of normal light to commencement f minimum	207
ration of minimum	313
m end of minimum to resumption of normal ight	207
	727

Total period of light change = 1·99 years.

dle epoch of last minimum occurred in 1902 March 31.
variation, as given by Ludendorff, amounts to $0^{m}\cdot73$, or
35 to $4^{m}\cdot08$ (see *Astron. Nach.* 3918–19–20).

1. The magnitudes of the comparison stars adopted are as follows, being taken from the R.H.P.

		m.
η Aurigæ	... ...	3·26
θ „	... ...	2·70
ζ „	... ...	3·80
ι „	... ...	2·99

I may say that the whole of the observations were made practically with the naked eye.

Before proceeding further I should like to remark that little or no importance is attached to the second decimal in the deduced magnitudes of *ε Aurigæ.* The comparisons were generally made in tenths of a magnitude; the two decimals come out when deducing the brightness from the magnitudes of the comparison stars which are given to two places of decimals in the R.H.P.

The observations, as contained in the list, have been plotted on square-ruled paper, the ordinate representing one magnitude in brightness corresponding in length to the abscissa for one-third of a year. Three methods have been adopted: 1. The magnitudes were all plotted direct from the list, and the points joined. The result is a series of zigzag lines for each season, all of which, with the exception of three observations in the year 1902, run fairly near the line representing $3^{m}{\cdot}0$. The three observations of 1902, however, are much below this, their mean being practically $4^{m}{\cdot}0$. For all the period under discussion, excluding 1902, the magnitudes are absolutely comprised within the limits 2·47 and 3·53. It is noticed incidentally that observations in April or May are usually higher (brighter) than any others. These curves are not reproduced here.

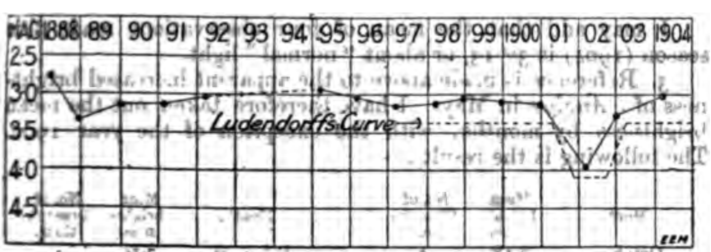

Fig. 1.

2. In order to smooth the asperities in the curves or lines just referred to, the mean brightness for each "season" has been taken, and the results plotted. This is represented in fig. 1. A glance at this diagram shows the brightness of the star to have been fairly constant, except in the season 1901–02, when there was a marked diminution of light corresponding to about 1 m.

d in figures, the mean brightness for seasons is as

on.	Magnitude.	No. of Observations.	Season.	Magnitude.	No. of Observations.
	2·80	2	1897	3·17	11
1889	3·35	11	1898	3·11	15
1890	3·18	8	1898–1899	3·08	19
	3·12	7	1899–1900	3·10	15
	3·05	8	1900–1901	3·13	12
al			1902	3·97	3
	2·96	1	1902–1903	3·26	5
	3·06	4	1904	3·04	9

rposed in fig. 1 is the light curve as deduced by Ludend it is at once seen that my observations support his actly, so far as the year 1902 is concerned. I regret some reason or another I did not make more observa- 1902 and 1903, whence the shape of the light curve ve been more accurately determined for the period of fluctuation. I have no observations bearing on the minimum in 1874–1875.

This increase is, I believe, subjective, and due to the difficult conditions under which the star is observed in April and May.

ε Aurigæ is a circumpolar star for the latitude of London, and as the year advances it can only be seen low down on the northern horizon with a background of bright twilight. One would imagine that with a brighter background there would be a tendency to make or estimate the star fainter than usual on this very account. Our curve, however, indicates the reverse of this; and as the observations are differential, or made by comparison with other stars, I am rather inclined to attribute the apparent increase in brightness to "position angle"—that is, to the different angle made with the vertical by the line joining the variable and the comparison star compared with the same angle when the constellation is higher in the sky. For example, I have noted more than once when observing in May that *ι Aurigæ* is getting vertically below ε, and immersed in the mists of the horizon.

There is a moral in all this for variable-star observers. Do not tire in watching a variable such as the one now in question, or *α Cassiopeiæ*, *α Orionis*, &c. One may observe for years without any change, and when one least expects it an important and marked change may occur. Although, according to Ludendorff's result, no further change is due for twenty-five years, yet I would urge observers to keep a watch on *ε Aurigæ* with a view to confirming the remarkable result already announced.

Observations of (*Ch.* 1768) *ε Aurigæ.*

Date.		Mag.	Remarks.
1888.			
Mar.	18	2·8	
	30	2·8	
Nov.	30	3·0	
Dec.	8	3·53	
	24	3·53	
	29	3·4	
1889.			
Jan.	29	3·4	
Feb.	20	3·46	
	27	3·26	
Mar.	4	3·4	
	5	3·4	
Apr.	17	3·4	
	21	3·06	
Dec.	18	3·4	
	20	3·1	
	24	3·1	

Date.		Mag.	Remarks.
1890.			
Jan.	23	3·16	*
Feb.	13	3·1	*
	20	3·16	*
Mar.	19	3·16	*
	29	3·3	*
1891.			
Jan.	9	3·4	*
Mar.	2	3·06	*
	5	3·16	*
	8	2·93	*
	10	3·08	*
	20	3·1	* Moonlight
Apr.	2	3·08	*
1892.			
Jan.	1	3·0	*
	3	3·1	*
	5	3·0	* Moonlight

Mag.	Remarks.
3·06	*
3·01	*
3·1	*
3·1	*
3·0	* Moonlight
al	
2·96	
3·16	
3·06	
29·6	Sky hazy
3·06	
3·01	
3·26	
3·17	
3·17	

Date.		Mag.	Remarks.
1898.			
May	10	2·78	
Dec.	19	3·30	Moonlight
	20	3·32	Moonlight
	22	3·12	
	29	2·95	
1899.			
Jan.	14	2·72	
	26	3·12	Moonlight
Feb.	2	3·15	
	22	2·92	
	27	3·12	Sky poor
	28	3·07	
Mar.	1	3·10	
	2	2·88	Sky poor
	4	3·08	
	5	3·22	
	9	3·22	

Date.	Mag.	Remarks.
1900.		
Nov. 27	3·06	Observations by W. E. Besley
Dec. 13	3·18	
15	3·18	
19	3·18	
21	3·17	
1901.		
Feb. 5	3·02	Moonlight
14	3·02	
15	3·07	
Mar. 15	3·07	
22	3·27	ι seemed very bright
1902.		
Apr. 16	4·0 ±	"Reliable, I think; but it is a colder white tint than ζ"
May 4	3·70	Bright twilight
10	4·20	Compared only with ζ as ι was too near the horizon

Date.	Mag.	Remarks.
1902.		
Dec. 24	3·39	
1903.		
Jan. 23	3·17	
28	3·20	
Feb. 23	3·31	
Mar. 3	3·25	"Most difficult to judge"
1904.		
Jan. 16	3·22	
19	3·22	
Feb. 6	3·12	Mean of two observations
13	3·17	
15	3·02	
Mar. 10	3·02	
Apr. 9	2·92	
12	3·22	ι looked reddish
May 2	2·47	Bright twilight

Telescopic Observation of a Meteor Trail. By W. Shackleton, A.R.C.Sc. (Lond.)

Whilst making a search for Encke's Comet towards midnight of October 12 I was startled by the field of view becoming suddenly illuminated, and on moving the telescope a few minutes in right ascension a bright ribbon-like streak came at once into view, which I was astonished to find sinuous and double. Glancing momentarily to the sky a long trail, evidently left by a meteor, was visible; moreover the trail appeared perfectly straight as far as the naked eye could judge. There was no doubt, however, that the trail, when observed under a magnifying power of 46, was irregular, the deviations bearing a strong resemblance to the path of an electric spark through air, except that the contortions were smaller and less rigid than is usually shown when the electric current takes the path of least resistance. The field of view of the telescope was 40′·5, and on tracing the trail by moving the telescope some three or four kinks were visible in each succeeding field.

The path of the meteor lay nearly in a circle of right ascension, and a movement of the telescope in declination showed that the whole trail was *marked by these undulations*, with here

longitudes are reckoned in the plane of the Moon's
the axis of reference being the radius which passes
the mean centre of the visible disc. This axis therefore
with the Moon, and is not fixed in space.
inclination of the Moon's equator to the ecliptic is taken
3, the value used in the *Nautical Almanac*.
physical librations in longitude and latitude, as given by
r Franz's formulæ, have been applied; their values are
nted separately, so that those who prefer to use Hayn's
nts (*Ast. Nach.* 3956) can do so. His longitude coefficient
t one quarter of Franz's. Thus to reduce to Hayn's
e apply three-quarters of the printed physical libra-
longitude with its own sign to Sun's colongitude,
h reversed sign to selenographical longitude of the

colongitude of the Sun is 90° (or 450°) *minus* his
aphical longitude. It is numerically equal to the seleno-
l longitude of the morning terminator reckoned eastward
e mean centre of the disc. Hence its value is approxi-
270°, 0°, 90°, 180° at new Moon, first quarter, full Moon,
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of course 180° greater or less than that of the morning

positive direction is that towards the Mare Crisium. North latitudes are considered positive.

Then

$$\text{sine Sun's altitude} = \sin L \sin N + \cos L \cos N \sin (K+M).$$

In the second case let ξ, η, ζ be the direction cosines of the given point. The axes are (1) that diameter of the Moon's equator which is 90° from the mean centre of the disc; (2) the Moon's polar axis; (3) the diameter through the mean centre of the disc. The positive directions are as above. Mr. Saunder has issued some maps of portions of the Moon's surface from which the co-ordinates ξ, η, ζ can be taken at sight.

Then the Sun's direction cosines are:

$$\cos K \cos L, \ \sin L, \ \sin K \cos L,$$

and sine Sun's altitude

$$= \xi \cos K \cos L + \eta \sin L + \zeta \sin K \cos L.$$

Neither formula is convenient when the Sun's altitude is very great, for an angle near 90° cannot be accurately determined from its sine. However, when the Sun is high the shadows are so inconspicuous that it is not necessary to compute his altitude with great accuracy.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.*:
1904 *October* 17.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

APPENDIX TO VOL. LXV.

[*From Proceedings of the Royal Society, Vol. LXXIV.*]

With indication of the original pagination.

No. 1.

CONTENTS.

Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Sel. Long. of the Earth.	Lat.	Physical Libration. Long.	Lat.	C.
°	°	°	°	°	°	°
75·99	−1·52	+1·45	−6·06	−·029	+·015	17·60
88·17	−1·52	+3·20	−6·48	−·028		12·53
100·35	−1·52	+4·73	−6·46	−·027		6·63
112·53	−1·53	+5·90	−6·03	−·026		0·38
124·72	−1·53	+6·63	−5·25	−·025		354·25
136·91	−1·53	+6·86	−4·20	−·024		348·65
149·11	−1·53	+6·63	−2·96	−·024		343·89
161·31	−1·53	+6·00	−1·61	−·023		240·11
173·52	−1·52	+5·03	−0·22	−·024	+·015	337·40
185·74	−1·52	+3·82	+1·15	−·025	+·016	335·75
197·97	−1·52	+2·48	+2·46	−·026		335·14
210·20	−1·51	+1·08	+3·66	−·027		335·54
222·43	−1·51	−0·28	+4·70	−·028		336·93
234·67	−1·51	−1·53	+5·54	−·029		339·28
246·91	−1·50	−2·64	+6·15	−·029		342·53
259·16	−1·50	−3·55	+6·48	−·030		346·65
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Lat. of the Earth.	Physical Libration. Long.	Lat.	C.
1905.	°	°	°	°	°	°	°
June 24	180·11	−1·32	+1·60	+3·57	−·010	+·017	335·32
25	192·33	−1·30	+0·25	+4·64	−·011		336·42
26	204·56	−1·28	−1·06	+5·52	−·011		338·47
27	216·80	−1·27	−2·24	+6·16	−·012		341·45
28	229·04	−1·25	−3·25	+6·54	−·013		345·29
29	241·29	−1·24	−4·02	+6·63	−·013		349·92
30	253·54	−1·23	−4·54	+6·39	−·013		355·19
July 1	265·79	−1·21	−4·79	+5·84	−·013		0·87
2	278·05	−1·20	−4·80	+4·96	−·012		6·65
3	290·30	−1·18	−4·59	+3·79	−·011		12·16
4	302·55	−1·17	−4·20	+2·40	−·010		17·01
5	314·80	−1·16	−3·64	+0·85	−·009		20·87
6	327·04	−1·14	−2·94	−0·77	−·007		23·49
7	339·27	−1·13	−2·13	−2·36	−·005		24·75
8	351·50	−1·11	−1·23	−3·81	−·003	+·017	24·57
9	3·72	−1·10	−0·23	−5·04	−·001	+·018	22·98
10	15·94	−1·08	+0·82	−5·96	+·001		20·05
11	28·15	−1·06	+1·89	−6·51	+·003		15·90
12	40·35	−1·04	+2·92	−6·66	+·005		10·77
13	52·55	−1·02	+3·84	−6·41	+·006		4·94
14	64·74	−1·00	+4·58	−5·78	+·008		358·82
15	76·93	−0·97	+5·08	−4·83	+·009		352·84
16	89·13	−0·95	+5·29	−3·62	+·009		347·38
17	101·32	−0·93	+5·17	−2·25	+·010		342·78
18	113·51	−0·90	+4·74	−0·79	+·010		339·22
19	125·71	−0·88	+4·01	+0·68	+·010		336·77
20	137·91	−0·85	+3·02	+2·08	+·009		335·45
21	150·12	−0·83	+1·86	+3·38	+·009		335·20
22	162·33	−0·80	+0·57	+4·49	+·008		336·02
23	174·54	−0·78	−0·75	+5·46	+·007		337·73
24	186·76	−0·75	−2·03	+6·16	+·007		340·40
25	198·99	−0·73	−3·18	+6·61	+·006		343·93
26	211·23	−0·70	−4·14	+6·77	+·006	+·018	348·26
27	223·46	−0·68	−4·84	+6·62	+·005	+·019	353·28
28	235·71	−0·66	−5·25	+6·14	+·005		358·82
29	247·96	−0·64	−5·34	+5·34	+·005		4·61
30	260·21	−0·62	−5·11	+4·22	+·006		10·29
31	272·45	−0·59	−4·58	+2·84	+·007	+·019	15·47

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Physical Libration. Long.	Physical Libration. Lat.	C.
1905.	°	°	°	°	°	°	°
Aug. 1	284.70	−0.57	−3.79	+1.27	+.008	+.019	19.77
2	296.95	−0.55	−2.80	−0.41	+.010		22.86
3	309.20	−0.53	−1.68	−2.08	+.012		24.54
4	321.44	−0.51	−0.48	−3.62	+.013		24.73
5	333.67	−0.49	+0.72	−4.93	+.015		23.44
6	345.90	−0.46	+1.88	−5.93	+.017		20.77
7	358.12	−0.44	+2.93	−6.55	+.019		16.89
8	10.33	−0.41	+3.85	−6.77	+.021		12.00
9	22.54	−0.39	+4.59	−6.59	+.022		6.40
10	34.74	−0.36	+5.12	−6.04	+.023		0.44
11	46.93	−0.33	+5.42	−5.16	+.024		354.50
12	59.12	−0.30	+5.47	−4.01	+.025		348.96
13	71.31	−0.27	+5.28	−2.67	+.025		344.13
14	83.50	−0.24	+4.83	−1.22	+.026		340.26
15	95.68	−0.21	+4.15	+0.25	+.025	+.019	337.46
16	107.87	−0.18	+3.25	+1.71	+.025	+.020	335.77
17	120.06	−0.15	+2.18	+3.06	+.024		335.18
18	132.25	−0.12	+0.97	+4.26	+.023		335.65
19	144.45	−0.09	−0.32	+5.27	+.022		337.09
20	156.65	−0.06	−1.64	+6.05	+.021		339.47
21	168.85	−0.03	−2.91	+6.57	+.020		342.70
22	181.06	−0.01	−4.07	+6.82	+.019		346.74
23	193.28	+0.02	−5.05	+6.76	+.018		351.47
24	205.50	+0.05	−5.78	+6.39	+.018		356.75
25	217.73	+0.07	−6.19	+5.71	+.018		2.38
26	229.96	+0.10	−6.25	+4.71	+.018		8.08
27	242.19	+0.12	−5.92	+3.42	+.019		13.47
28	254.43	+0.14	−5.21	+1.90	+.020		18.17
29	266.67	+0.16	−4.14	+0.22	+.021		21.80
30	278.91	+0.19	−2.78	−1.51	+.022		24.07
31	291.15	+0.21	−1.22	−3.15	+.023		24.82
Sept. 1	303.39	+0.24	+0.43	−4.59	+ 025		23.98
2	315.62	+0.26	+2.04	−5.71	+.027		21.64
3	327.84	+0.28	+3.51	−6.45	+.028	+.020	17.96
4	340.06	+0.31	+4.74	−6.77	+.030	+.021	13.21
5	352.27	+0.33	+5.68	−6.67	+0.32		7.69
6	4.48	+0.36	+6.29	−6.18	+.033		1.76
7	16.67	+0.39	+6.57	−5.36	+.034	+.021	355.82

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1905. Sept. 8	28°·87	+0°·42	+6°·54	−4°·28	+°·035	+°·021	350°·22
9	41·05	+0·45	+6·23	−2·99	+·035		345·27
10	53·23	+0·48	+5·67	−1·58	+·035		341·19
11	65·41	+0·51	+4·91	−0·12	+·035		338·13
12	77·58	+0·54	+3·97	+1·33	+·036		336·15
13	89·76	+0·57	+2·89	+2·70	+·035		335·26
14	101·93	+0·60	+1·70	+3·94	+·033		335·42
15	114·11	+0·62	+0·43	+4·99	+·032		336·59
16	126·29	+0·65	−0·88	+5·83	+·031		338·71
17	138·46	+0·68	−2·19	+6·41	+·030		341·70
18	150·64	+0·70	−3·46	+6·72	+·029		345·48
19	162·84	+0·73	−4·63	+6·74	+·028	+·021	349·96
20	175·03	+0·75	−5·64	+6·47	+·027	+·022	355·00
21	187·23	+0·77	−6·44	+5·89	+·026		0·43
22	199·43	+0·79	−6·95	+5·02	+·026		6·00
23	211·64	+0·82	−7·10	+3·87	+·026		11·41
24	223·85	+0·84	−6·85	+2·47	+·027		16·33
25	236·07	+0·85	−6·15	+0·89	+·027		20·39
26	248·30	+0·87	−5·01	−0·80	+·028		23·24
27	260·52	+0·89	−3·46	−2·48	+·030		24·67
28	272·75	+0·91	−1·62	−4·01	+·031		24·50
29	284·97	+0·93	+0·39	−5·27	+·032		22·71
30	297·19	+0·95	+2·40	−6·16	+·034		19·42
Oct. 1	309·41	+0·97	+4·22	−6·62	+·035		14·86
2	321·63	+0·99	+5·74	−6·62	+·036		9·36
3	333·83	+1·01	+6·84	−6·21	+·037		3·35
4	346·03	+1·03	+7·49	−5·45	+·038		357·25
5	358·22	+1·05	+7·70	−4·40	+·039		351·46
6	10·41	+1·07	+7·51	−3·16	+·039		346·32
7	22·59	+1·10	+6·98	−1·78	+·039		342·04
8	34·76	+1·12	+6·19	−0·35	+·039		338·76
9	46·93	+1·14	+5·19	+1·07	+·038		336·54
10	59·09	+1·16	+4·05	+2·43	+·037		335·39
11	71·25	+1·18	+2·82	+3·66	+·036		335·30
12	83·41	+1·20	+1·53	+4·73	+·035		336·21
13	95·57	+1·22	+0·23	+5·59	+·033		338·09
14	107·73	+1·24	−1·07	+6·21	+·031		340·87
15	119·89	+1·26	−2·34	+6·56	+·030	+·022	344·45

Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Physical Libration. Long.	Physical Libration. Lat.	C.
132°·05	+1°·27	−3°·56	+6°·62	+°·028	+°·023	348°·75
144·21	+1·29	−4·70	+6·40	+·027		353·63
156·38	+1·30	−5·70	+5·89	+·027		358·91
168·55	+1·32	−6·53	+5·10	+·026		4·37
180·73	+1·33	−7·12	+4·05	+·025		9·73
192·91	+1·34	−7·40	+2·77	+·025		14·70
205·10	+1·35	−7·30	+1·30	+·026		18·97
217·29	+1·36	−6·77	−0·28	+·026		22·23
229·49	+1·37	−5·76	−1·89	+·027		24·22
241·70	+1·38	−4·30	−3·43	+·028		24·76
253·90	+1·39	−2·45	−4·77	+·029		23·71
266·12	+1·40	−0·33	−5·79	+·030		21·08
278·33	+1·40	+1·86	−6·39	+·031		16·98
290·53	+1·41	+3·92	−6·53	+·033		11·70
302·74	+1·42	+5·68	−6·22	+·033		5·65
314·94	+1·43	+6·99	−5·52	+·034		359·32

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Physical Libration. Long.	Physical Libration. Lat.	a.
1905.	°	°	°	°	°	°	°
Nov. 23	234·66	+1·50	−2·93	−5·51	+·019	+·024	22·51
24	246·84	+1·50	−1·02	−6·22	+·020		19·00
25	259·05	+1·50	+1·03	−6·50	+·021		14·26
26	271·24	+1·49	+3·04	−6·32	+·021		8·48
27	283·44	+1·49	+4·82	−5·71	+·022		2·11
28	295·63	+1·48	+6·22	−4·73	+·022		355·67
29	307·82	+1·48	+7·13	−3·49	+·023		349·69
30	320·01	+1·48	+7·54	−2·09	+·022		344·55
Dec. 1	332·18	+1·48	+7·45	−0·62	+·022		340·50
2	344·36	+1·47	+6·95	+0·84	+·021		337·60
3	356·52	+1·47	+6·10	+2·23	+·020		335·87
4	8·69	+1·46	+5·01	+3·48	+·018		335·25
5	20·84	+1·45	+3·76	+4·57	+·017		335·66
6	32·98	+1·44	+2·43	+5·45	+·015	+·024	337·06
7	45·13	+1·44	+1·11	+6·09	+·013	+·025	339·36
8	57·27	+1·43	−0·16	+6·47	+·011		342·54
9	69·40	+1·42	−1·34	+6·58	+·009		346·50
10	81·54	+1·40	−2·40	+6·39	+·007		351·14
11	93·67	+1·39	−3·34	+5·91	+·005		356·30
12	105·80	+1·38	−4·13	+5·15	+·005		1·76
13	117·93	+1·36	−4·78	+4·13	+·004		7·23
14	130·06	+1·34	−5·28	+2·90	+·003		12·41
15	142·20	+1·33	−5·62	+1·49	+·003		16·98
16	154·34	+1·31	−5·76	−0·01	+·002		20·66
17	166·48	+1·29	−5·76	−1·54	+·003		23·24
18	178·64	+1·28	−5·30	−3·01	+·003		24·58
19	190·80	+1·26	−4·64	−4·34	+·003		24·57
20	202·96	+1·24	−3·66	−5·43	+·004		23·17
21	215·13	+1·22	−2·38	−6·20	+·005		20·38
22	227·31	+1·20	−0·87	−6·57	+·006		16·27
23	239·50	+1·19	+0·78	−6·52	+·006		11·02
24	251·68	+1·17	+2·42	−6·02	+·008		4·96
25	263·87	+1·16	+3·91	−5·14	+·008	+·025	358·52
26	276·06	+1·14	+5·13	−3·93	+·008	+·026	352·25
27	288·25	+1·12	+5·96	−2·52	+·008		346·62
28	300·44	+1·11	+6·36	−0·99	+·007		342·00
29	312·62	+1·09	+6·34	+0·54	+·006		338·56
30	324·80	+1·07	+5·91	+2·01	+·005		336·36
31	336·97	+1·05	+5·15	+3·35	+·004	+·026	335·36

longitudes are reckoned in the plane of the Moon's the axis of reference being the radius which passes the mean centre of the visible disc. This axis therefore vith the Moon, and is not fixed in space.

inclination of the Moon's equator to the ecliptic is taken 3, the value used in the *Nautical Almanac*.

physical librations in longitude and latitude, as given by r Franz's formulæ, have been applied; their values are nted separately, so that those who prefer to use Hayn's nts (*Ast. Nach.* 3956) can do so. His longitude coefficient t one quarter of Franz's. Thus to reduce to Hayn's e apply three-quarters of the printed physical libra- longitude with its own sign to Sun's colongitude, h reversed sign to selenographical longitude of the

colongitude of the Sun is 90° (or 450°) *minus* his aphical longitude. It is numerically equal to the seleno- l longitude of the morning terminator reckoned eastward e mean centre of the disc. Hence its value is approxi- 70°, 0°, 90°, 180° at new Moon, first quarter, full Moon, rter respectively. The longitude of the evening termi- of course 180° greater or less than that of the morning

positive direction is that towards the Mare Crisium. North latitudes are considered positive.

Then

$$\text{sine Sun's altitude} = \sin L \sin N + \cos L \cos N \sin (K+M).$$

In the second case let ξ, η, ζ be the direction cosines of the given point. The axes are (1) that diameter of the Moon's equator which is 90° from the mean centre of the disc ; (2) the Moon's polar axis ; (3) the diameter through the mean centre of the disc. The positive directions are as above. Mr. Saunder has issued some maps of portions of the Moon's surface from which the co-ordinates ξ, η, ζ can be taken at sight.

Then the Sun's direction cosines are :

$$\cos K \cos L, \ \sin L, \ \sin K \cos L,$$

and sine Sun's altitude

$$= \xi \cos K \cos L + \eta \sin L + \zeta \sin K \cos L.$$

Neither formula is convenient when the Sun's altitude is very great, for an angle near 90° cannot be accurately determined from its sine. However, when the Sun is high the shadows are so inconspicuous that it is not necessary to compute his altitude with great accuracy.

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1904 *October* 17.

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[redacted]

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With indication of the original pagination.

No. 1.

CONTENTS.

Lines of Titanium, Iron, and Chromium in the
feric Spectrum." By Sir J. NORMAN LOCKYER, K.C.B.,
F.R.S., and F. E. BAXANDALL, A.R.C.S. Received
1904.

publications it has been shown that the enhanced lines
e metals are prominent in the spectra of α Cygni* and
nosphere,† while it is generally recognised that the lines
oferic spectrum are mainly the equivalents of lines in the
metals. In connection with the work on enhanced lines
noted that some of them, at least, appear to correspond
ively weak solar lines to which Rowland has attached no
the object of possibly tracing some of the unorigined
heir source, a careful comparison has been made between
lines shown in the photographic spark spectra of titanium,
mium, and the solar lines. The photographs used for
were all taken with a Rowland grating, under exactly

were then compared with Rowland's solar wave-lengths, and in cases of close agreement with solar lines it was deemed probable that the two lines were really identical. In this connection, however, the relative intensities of the solar and enhanced lines were, to a great extent, taken into account in judging whether a solar line could be accepted as the analogue of a metallic line.

The three elements investigated are dealt with separately. The tables show the wave-lengths of the enhanced lines as reduced from the most recent and best photographs, their intensities in spark and arc spectra, the wave-lengths of Rowland's solar lines to which they probably correspond, and the origins, if any, to which Rowland has attributed such solar lines.

The wave-lengths of some of the enhanced lines differ in the second decimal place from those published* previously for the same lines. More weight can be given to the present wave-lengths, as in the photographs from which they have been reduced the lines are more sharply defined than in the earlier photographs employed. In the case of chromium a much more extended list of enhanced lines than the previous one has been obtained.

The numbers in the last column refer to the notes at the end of each table.

Titanium.

λ. Enhanced Ti lines.	Intensity.		Fraunhoferic lines (Rowland).		Rowland's origin.	Notes appended.
	Spark, max. 10.	Arc, max. 10.	λ.	Int., max. 1000.		
3813·54	4	1—2	3813·54	2	C	1
3814·72	5	2—3	3814·74	3	C	2
3836·23	4	1—2	3836·23	2	—	3
3900·68	10	4	3900·68	5	Ti-Fe-Zr	[1]
3913·61	10	4	3913·61	5	Ti-Fe	[2]
3932·16	4	trace	3932·16	1	Ti	
3987·75	1	0	3987·76	2	Ti ?	
4012·54	5	1	4012·54	4	Ti	
4025·29	3	1	4025·29	3	Ti	
4028·50	6	1	4028·50	4	Ti	
4053·98	5	trace	4053·98	3	Fe-Ti	[3]
4055·19	2	1	4055·19	3	Ti-Fe	[4]
4161·70	2—3	0	4161·68	4	—	4
4163·82	10	2	4163·82	4	Ti, Cr	[5]
4172·07	10	1	4172·07	2	Ti-Fe	[6]
4173·70	3	0	4173·71	3	—	[7]
4174·20	2	0	4174·24	0	—	
4184·49	1	0	4184·47	2	—	[8]

* 'Roy. Soc. Proc.,' vol. 65, p. 451.

Titanium—*continued.*

Intensity.		Fraunhoferic lines (Rowland).		Rowland's origin.	Notes appended.
park, ax. 10.	Arc, max. 10.	λ.	Int. max. 1000.		
2	0	4227·47	1	—	5
6	2	4290·38	2	Ti	
7	3	4294·20	2	Ti	
6	1—2	4300·21	3	Ti	
3	1—2	4302·09	2	Ti	
7	1—2	4308·08	6	Fe	6
7	1—2	4313·03	3	Ti	
8	1	4315·14	3	Ti	
2	0	4316·96	1	Ti ?	
3	1	4321·12	2	—	
2	trace	4330·41	1	—	
2	trace	4330·87	2	Ti-Ni	[9]
8	4	4338·08	4	Ti	
3	1	4341·53	2	Ti ?	

Notes on *p* Ti-Solar Lines.

(The figures at the head of each note refer to Rowland's solar lines.)

[1.] **3900·68 (5), Ti-Fe-Zr.**—The titanium line involved in the solar line is one of the very strongest in the spark spectrum. The iron line is only a weak one, and, in the light of other adjacent iron lines of equal intensity, would of itself only produce a solar line of intensity 2 or 3. In apportioning the weights to the various elements which possibly take part in the formation of the solar line, zirconium can be almost ignored. There are many far stronger lines of zirconium than the one in question, which are not represented in the sun at all. It would appear, then, that the solar line 3900·68 is really made up of the *p* Ti and Fe lines in about equal proportions.

[2.] **3913·61 (5), Ti-Fe.**—It is very doubtful whether Fe takes any part in the production of this solar line. There is no such iron line recorded by either Kayser and Runge or Exner and Haschek, and there is no trace of a line in any of the Kensington photographs. The titanium line is a very prominent one in the spark spectrum, and quite capable of producing the solar line of itself.

[3.] **4053·98 (3), Fe-Ti.**—The iron line is an extremely faint one, while the titanium line is well marked. The solar line is probably a composite one, but more attributable to titanium than iron.

[4.] **4055·19 (3), Ti-Fe.**—The iron and titanium lines are coincident, and about equally strong. Solar line probably due to both.

[5.] **4163·82 (4), Ti-Cr.**—Both the titanium and chromium lines are well marked in their respective spectra. The former seems to be slightly less refrangible than the other. The solar line is probably a very close double, and due to both Ti and Cr.

[6.] **4172·07 (2), Ti-Fe.**—The iron line is extremely weak, while the *p* Ti line is one of the strongest in the spectrum. The solar line is probably due chiefly to Ti.

[7.] **4173·71 (1); no origin by Rowland.**—The mean result of two measurements of this enhanced titanium line gives λ 4173·71. Its identity with the solar line is therefore well established.

[8.] **4184·47 (2); no origin by Rowland.**—The published wave-length of this enhanced titanium line was 4184·40. A re-estimation from a later grating photograph gives as a resulting wave-length 4184·49. There is little doubt of its identity with the solar line 4184·47.

[9.] **4330·87 (2), Ti-Ni.**—The nickel line is an exceedingly weak one, and it is doubtful whether the solar line is partially produced by it. Rowland, in a foot-note in his 'Tables of Solar Wave-Lengths,' says: "This is a weak, hazy, nickel line. It is on the red edge of the solar line, and the Ti line is nearer the centre."

[10.] **4374·98 (0), Zr.**—The published wave-length of the enhanced titanium line was 4374·90. A re-estimation from a better photograph gives 4374·99. It is probably identical with the weak solar line 4374·98, which Rowland ascribes to Zr.

[11.] **4399·94 (3), Ti-Cr.**—The chromium line, although apparently coincident with the titanium and solar lines, is a very weak one. On the other hand, the titanium line is quite well marked. The solar line is therefore probably due chiefly to titanium.

[12.] **4411·24 (1), Cr.**—Re-measurement of the proto-titanium line gives λ 4411·24. It is apparently coincident both with the chromium and solar lines. The chromium line is a weak one, whereas the titanium line is well marked, and there is little doubt that the solar line is partially, if not chiefly, due to titanium.

[13.] $\left.\begin{array}{l}\textbf{4529·66 (1)}\\ \textbf{4529·73 (1)}\end{array}\right\}$ **No origin by Rowland.**—The published wave-length of the enhanced titanium line was 4529·60. Re-measurement from the latest grating photograph gives λ 4529·69. *It is doubtful which* of the two solar lines, 4529·66

um line represents. It is quite possible that the latter is a very may account for both solar lines.

(6), Ti-Co.—Both the titanium and cobalt lines are well marked e spectra, and there is little doubt that the solar line is com- o.

(6), Ti-Co.—The titanium and cobalt lines are apparently s each is a strong line in its own spectrum, the solar line is nded of both in about equal proportion.

(4), Ti-Ni.—The enhanced titanium line is a very weak one, and that Ni is the chief origin of the solar line.

Iron.

Intensity.		Fraunhoferic lines (Rowland).			Notes appended.
ark, x. 10.	Arc. max. 10.	λ.	Int., max. 1000.	Origin.	
—3	0	3839 ·76	2	Fe	
—3	1	3846 ·55	2	Fe	
3	1—2	3863 ·89	3	Fe	
4	1—2	3871 ·96	2	Fe	
1	0	3906 ·17	00	—	

1. Probably partly due to the enhanced Fe line, in addition to Mn and Cr.
2. Solar line probably due partly to *p* Fe. K and R's λ 4055·63 (4).
3. Solar line probably compounded of the *p* Fe and Mn lines.
4. The *p* Fe line is apparently slightly more refrangible than solar line 4462·37.
5. This *p* Fe line is probably identical with Rowland's solar line 4522·81 rather than with 4522·69, to which he gives a Fe ? origin.

Notes on Certain *p* Fe-Solar Lines.

[1.] λ 4233·33 (4).—This solar line was ascribed by Rowland to Mn-Fe in his "Preliminary Table of Solar Wave-lengths." In the revised table* the Fe origin is discarded and the sole origin given as Mn. There appears to be, however, no evidence for the line being due to manganese. There is no trace whatever of a line in this position in any of the Kensington photographs of the manganese spectrum, and no such line is given by Hasselberg† in his comprehensive list of manganese arc lines. Although the arc line of iron at the corresponding wave-length is exceedingly weak—in many photographs it does not occur at all—there is no doubt about there being a prominent line in the spark spectrum. The solar line in question is probably due solely to iron, and is the counterpart of the enhanced line of that metal. In α Cygni the line 4233·33 is quite an outstanding line and one of the very strongest in the spectrum.

[2.] 4351·93 (5), Cr.—This solar line is ascribed by Rowland solely to Cr. Although the chromium line is a moderately strong one, it is scarcely likely that its solar equivalent would be as strong as that of the chromium line 4289·89, one of the very strongest lines in the spectrum of that element. The two solar lines mentioned being, however, of the same intensity, in all probability that at λ 4351·93 is partially due to some other element. The strongly enhanced Fe line 4351·93 is apparently exactly coincident with the Cr line, and as other similarly enhanced Fe lines occur amongst the Fraunhoferic lines, it is probable that the solar line in question is compounded of the iron and chromium lines.

In α Cygni there is a corresponding well-marked line which, in the light of the complete absence from the stellar spectrum of chromium arc lines, can only be attributed to proto-iron. This is the more likely, as the other enhanced lines of iron are so prominent in the α Cygni spectrum.

This line in stellar spectra has been attributed by Scheiner to the magnesium arc line 4352·08, and on its behaviour with respect to the stellar representative of the characteristic spark line of magnesium 4481·3, he has based conclusions‡ on the relative temperatures of the absorbing atmospheres of various stars. Such conclusions are not trustworthy, as the origin of the line is obviously not the same in all stellar spectra. In stars of the solar type the line is probably of a complex origin, Cr 4351·93, Mg 4352·08, and *p* Fe 4351·93, all being involved. In higher temperatures stars like α Cygni, Sirius, and Rigel there is abundant evidence in favour of a proto-Fe origin and little or none for either chromium or magnesium. Thus, other lines of Cr and Mg, which are similar in intensity and behaviour in their respective spectra to those mentioned above, are all unrepresented in these stellar spectra, whereas all the enhanced Fe lines of similar intensity and behaviour to the line 4351·93 are strongly represented in the same stellar spectra.

[3.] 4629·52 (6), Ti-Co.—It is doubtful whether the Ti and Co lines are collectively strong enough to account for the intensity of the solar line. The equally strong Co line 4663·59 only furnishes a solar line of intensity 0, and the stronger

* 'Ast. Phys. Jour.,' vol. 6, p. 384, 1897.
† 'Kongl. Sv. Vet. Akademiens Handlingar,' Bd. 30, No. 2.
‡ 'Ast. and Ast. Phys.,' vol. 13, p. 569.

corresponds to a solar line of intensity 2. It is scarcely likely, uperposition of the Ti and Co lines at 4629·60 would produce a ensity 6. The proto-iron line at the same wave-length probably iency in intensity. The enhanced line of iron 4515·51, which is rominence as 4629·60, has an equivalent solar line of intensity 3, line 4629·60 of itself produces a similar solar line, then the e solar 4629·60 could be easily accounted for. In fact, it is quite e solar line in question is built up of the lines at the same wave- to Ti, Co, and *p* Fe, and that the proto-iron line has, if anything, e in its production.

ly good corresponding line in the chromospheric spectrum, and, in of eclipse results by various observers, the origin of the line is as Ti-Co, presumably because they have established its identity hoferic line and accepted Rowland's origin as a correct and n the chromosphere it is probably chiefly due to *p* Fe, as the Co lines are there only weak, while the enhanced iron lines are here is also a corresponding line in the spectrum of α Cygni. he origin is evidently proto-iron only, as the arc lines of cobalt entirely missing from the stellar spectrum; whereas nearly all es are well seen.

Chromium.

Chromium—*continued.*

λ. Enhanced Cr lines.	Intensity.		Fraunhoferic lines (Rowland).		Rowland's origin.	Notes appended.
	Spark, max. 10.	Arc, max. 10.	λ.	Int., max. 1000.		
4592·23	4—5	0	4592·23	1	Cr	
4616·80	3—4	0	4616·80	1	—	
4618·97	8	0	4618·97	4	Fe	[2]
4634·25	8	0	4634·25	2	—	
4812·72	2—3	0	—	—	—	
4824·33	8	0	4824·33	3	Fe	6
4836·40	2—3	0	4836·42	0	—	
4848·44	6	0	4848·44	2	—	
4856·37	1	0	—	—	—	
4864·51	5	0	4864·51	1	—	
4876·59	5	0	4876·59	1	—	

1. Fe line and *p* Cr lines apparently coincident. Solar line probably compounded of both.
2. *p* Cr and Si lines exactly coincident. Solar line probably due to both, but mostly to Si.
3. Solar line probably due more to *p* Cr than Fe.
4. *p* Cr line possibly double.
5. Solar line possibly due partly to some other element.
6. Solar line probably compounded of Fe and *p* Cr lines.

Notes on Certain *p* Cr-Solar Lines.

[1.] λ 3979·66, Co (4).—This enhanced line of chromium is apparently coincident with a cobalt line, and also with the solar line λ 3979·664, to which Rowland assigns a cobalt origin. As the adjacent cobalt line 3958·07 is quite as strong as 3979·66, and only furnishes a solar line of intensity 2, it is not probable that the solar line corresponding to 3979·66 would be of intensity 4, unless a line of some other element were involved. It is very probable that the solar line in question is compounded of the *p* Cr and Co lines.

[2.] λ 4618·97, Fe (4).—This strongly enhanced Cr line is apparently coincident with the solar line 4618·97 (intensity 4), Rowland's origin for which is Fe. The nearest line of iron to this in Kayser and Runge's list is 4618·88 (2). Assuming that this is identical in position with the solar line, its intensity is far too low to account for the solar intensity. The closely adjacent iron line 4619·40, which is of intensity 6, gives a solar line of intensity 3, so that it is very improbable that the far weaker iron line 4618·21 will produce a solar line of intensity 4. There is little doubt that the solar line 4618·97 is chiefly accounted for by the strongly enhanced chromium line, but the iron line at the same position probably adds slightly to the solar intensity.

JNHOFERIC LINES DUE TO p Ti, p Fe, or p Cr.

ng table contains the Fraunhoferic lines which are, the present discussion, considered to be due, either tially, to enhanced lines of titanium, iron, or chromium. re-lengths have been adopted with the modification that in the decimals has been dropped, and the numbers earest second decimal. In such an inquiry as the present e done without affecting the validity of the results. In , the spark lines are generally of a wider and hazier e arc lines, and consequently their wave-lengths cannot o as great a degree of accuracy. Again, the conclusions ity of the solar and enhanced lines are not based on one ences only, but on the apparent agreement of a whole for each element.

een that some forty-two lines which were unorigined by here attributed to proto-titanium, proto-iron, or proto- Compared with the host of lines in Rowland's tables a very insignificant number, but the importance of

entirely absent from the arc spectrum, and that Rowland has identified the solar line with the arc equivalent of the enhanced line. Seeing, however, that most of these lines occur in stellar spectra, where hosts of stronger arc lines are missing; it will, perhaps, be more appropriate to designate them as of a proto-metallic origin even in the sun.

Solar Lines due either wholly or partially to Enhanced Lines of Ti, Fe, or Cr.

Fraunhoferic lines (Rowland).			Probable origin (Kensington).	Notes appended.
λ.	Int., max. 1000.	Origin.		
3813·54	2	C	*p* Ti	
3814·74	3	C	*p* Ti	
3836·23	2	—	*p* Ti	
3839·76	2	Fe	*p* Fe	
3846·55	2	Fe	*p* Fe	
3863·89	3	Fe	*p* Fe	
3865·67	7	Fe-C	Fe-*p* Cr	
3871·96	2	Fe	*p* Fe	
3900·68	5	Ti-Fe-Zr	*p* Ti-Fe	1
3905·66	12	Si	Si *p* Cr	
3906·17	00	—	*p* Fe	
3913·61	5	Ti-Fe	*p* Ti	2
3932·16	1	Ti	*p* Ti	
3935·97	2	Fe	*p* Fe	
3939·29	0	—	*p* Fe	
3979·66	4	Co	Co *p* Cr	
3987·76	2	Ti ?	*p* Ti	
4002·81	0	—	*p* Fe	
4012·54	4	Ti	*p* Ti	
4012·63	0	Cr	*p* Cr	
4025·29	3	Ti	*p* Ti	
4028·50	4	Ti	*p* Ti	
4048·91	5	Mn-Cr	Mn-Cr-*p* Fe	3
4053·98	3	Fe-Ti	*p* Ti-Fe	
4055·19	3	Ti-Fe	*p* Ti, Fe	
4055·70	6	Mn	Mn *p* Fe	4
4058·92	3	Fe-Cr	Cr *p* Fe	5
4145·91	1	—	*p* Cr	
4161·68	4	—	*p* Ti	6
4163·82	4	Ti-Cr	*p* Ti, Cr	
4172·07	2	Ti-Fe	*p* Ti	7
4173·62	3	—	*p* Fe	
4173·71	3	—	*p* Ti	
4174·24	0	—	*p* Ti	
4179·03	3	—	*p* Fe	
4184·47	2	—	*p* Ti	
4225·02	2	—	*p* Cr	
4227·47	1	—	*p* Ti	
4233·33	4	Mn	*p* Fe	8
4242·54	2	—	*p* Cr	
4252·79	0	—	*p* Cr	
4262·09 }	1	—	} *p* Cr	9
4262·14 }	1	—		

ar Lines due to Enhanced Lines of Ti, Fe, or Cr—*cont*

Fraunhoferic lines (Rowland).			Probable origin (Kensington).
λ.	Int., max. 1000.	Origin.	
4 ·38	2	—	*p* Cr
0 ·38	2	Ti	*p* Ti
4 ·20	2	Ti	*p* Ti
6 ·74	3	—	*p* Fe
0 ·21	3	Ti	*p* Ti
2 ·09	2	Ti	*p* Ti
2 ·35	2	Fe	*p* Fe
3 ·34	2	—	*p* Fe
8 ·08	6	Fe	Fe *p* Ti
3 ·03	3	Ti	*p* Ti
5 ·14	3	Ti	*p* Ti
6 ·96	1	Ti ?	*p* Ti
1 ·12	2	—	*p* Ti
0 ·41	1	—	*p* Ti
0 ·87	2	Ti-Ni	*p* Ti
8 ·08	4	Ti	*p* Ti
1 ·53	2	Ti ?	*p* Ti

Solar Lines due to Enhanced Lines of Ti, Fe, and Cr—*continued.*

Fraunhoferic lines (Rowland).			Probable origin (Kensington).	Notes appended.
λ.	Int., max. 1000.	Origin.		
4563·94	4	Ti	*p* Ti	
4572·16	6	Ti	*p* Ti	
4576·51	2	—	*p* Fe	
4584·02	4	Fe	*p* Fe	
4588·38	3	—	*p* Cr	
4590·13	3	—	*p* Ti	
4592·25	1	Cr	*p* Cr	
4616·81	1	—	*p* Cr	
4618·97	4	Fe	*p* Cr-Fe	14
4629·52	6	Ti Co	*p* Fe, Ti, Co	
4634·25	2	—	*p* Cr	
4635·49	0	—	*p* Fe	
4657·38	2	Ti ?	*p* Ti	
4824·33	3	Fe	Fe *p* Cr	
4836·42	0	—	*p* Cr	
4848·44	2	—	*p* Cr	
4864·51	1	—	*p* Cr	
4876·59	1	—	*p* Cr	

1. Zr negligible.
2. No evidence for Fe origin.
3. Chiefly due to Mn.
4. Chiefly due to Mn.
5. Chiefly due to *p* Cr.
6. Possibly due partially to some other element.
7. No evidence for Fe origin.
8. No evidence for Mn.
9. Doubtful which is really due to *p* Cr.
10. Evidence for Ni doubtful.
11. No evidence for Zr.
12. Chiefly due to *p* Ti.
13. Doubtful which is really due to *p* Ti.
14. Chiefly due to *p* Cr.

General Conclusions.

As a general summary of the results of the foregoing analysis it may be stated :—

1. The enhanced lines of titanium and iron are practically all represented in the Fraunhoferic spectrum, but in some cases the corresponding solar lines are compound, and only partly due to one or other of these metals.

2. The corresponding solar lines are, generally speaking, comparatively weak ones.

jority of the chromium enhanced lines occur in the n, though some appear to be missing.

the Fraunhoferic lines correspond to metallic lines special spectrum, and lacking in the arc, and probably for this ere left unorigined by Rowland.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXV. DECEMBER 9, 1904. No. 2

Professor H. H. TURNER, D.Sc., F.R.S., PRESIDENT, in the Chair.

William Allan, M.A., B.Sc., 88 Leamington Terrace, Edinburgh;
Ernest Cuthbert Atkinson, M.A., Erwood, Beckenham, Kent;
Colonel Arthur Henry Bagnold, R.E., Warren Wood, Shooters' Hill, S.E.;
Rev. D. B. Marsh, D.Sc., Hamilton, Ontario, Canada; and
William Newbold, 7 Broadwater Down, Tunbridge Wells,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended:

William Edward Raymond, Astronomical Observer, Sydney Observatory, New South Wales, Australia (proposed by H. C. Russell).

Sixty presents were announced as having been received since the last meeting, including, amongst others:

Galilei, Opere, Edizione Nazionale, vol. xiv., presented by the Italian Government; H. Draper and G. W. Ritchey, Construction

vered Glass Reflector, and on the Modern Reflecting
e and the Making and Testing of Optical Mirrors ; and
aler, Comparison of the Features of the Earth and the
esented by the Smithsonian Institution ; Porträtgallerie
onomischen Gesellschaft, presented by H. W. Tullberg ;
hittaker, a Treatise on Analytical Dynamics, presented
uthor.

ty charts of the Astrographic Chart, presented by the
bservatory, Greenwich ; spectrograms on the rotation of
ets, &c. (six prints), presented by Percival Lowell.

Completion of the Solution of the Main Problem in the Lunar Theory. By Ernest W. Brown, Sc.D., F.R.S.

completion of a laborious piece of work which has
many years for its execution furnishes a suitable oppor-

que le Soleil se mouvroit uniformément dans un cercle autour de la Terre." After some general remarks he writes: "Quelque chimérique cette question j'ose assurer que, si l'on réussissoit à en trouver une solution parfaite on ne trouveroit presque plus de difficulté pour déterminer le vrai mouvement de la Lune réelle. Cette question est donc de la dernière importance et il sera toujours bon d'en approfondir toutes les difficultés, avant qu'on en puisse espérer une solution complète." He then proceeds to find the solution, now known as the "variation orbit," as far as the fourth power of the only small parameter present. One may almost see in the few lines just quoted a germ of the magnificent work done by Poincaré on periodic orbits within the last twenty years.

The development of this idea of Euler is mainly due to G. W. Hill, who put the earlier steps into such a form that high accuracy could be obtained without excessive labour. J. C. Adams had also taken it up and worked at it in a somewhat similar manner. Hill determined the variation orbit and the principal part of the mean motion of the perigee, while Adams also found the variation orbit, but by a less powerful method, and the principal part of the mean motion of the node.

Before taking up a complete treatment from this stage it was necessary to consider as carefully as possible the amount of labour which would be demanded. The working value of a method of treatment is not really tested by the closeness with which the first or second approximation will make the further approximations converge quickly to the desired degree of accuracy; the real test is, perhaps, the ease with which the final approximation can be obtained. Here we have the essential difference between the present method and all other methods. The approximations of the latter proceed along powers of the disturbing force. Euler's idea was to approximate along powers of the other small constants present. This gives a more rapid convergence and a degree of certainty in knowing the limits of error of the final results which no other method approaches.

With this in view it was necessary to cast the equations of motion into such a form that the degree of accuracy demanded should be capable of being obtained with a reasonable amount of labour, and it must be made clear that this degree of accuracy had actually been attained when the work was completed. Precautions against errors of computation must be taken, and the results should, if possible, be expressed in such a form that comparison with those of previous theories is possible. These and other points are considered in the following paragraphs:—

First, every coefficient in longitude, latitude, and parallax which is as great as one-hundredth of a second of arc has been computed, and is accurate—apart from possible errors of calculation—to at least this amount. Hansen, indeed, gives his results to thousandths of a second, but certain of them are in

some tenths of a second; indeed, it was not possible to
l of them more accurately without much increasing the
f his calculations. Some of Delaunay's coefficients,
slow convergence, are not accurate to one second of arc.
tter of fact my results are obtained correctly to one-
th of a second, and there are comparatively few
ts greater than this quantity which have not been

d, the theory is expanded algebraically in powers of four
e parameters, the fifth (the ratio of the mean motions of
nd Moon) having its numerical value substituted at the
The last is known with a degree of certainty which
ll the possible needs of the theory, and the effect of any
change which may be made in its observed value can
deduced from Delaunay's purely literal theory. The
antage gained is due to the fact that slow convergence
divergence) occurs only along powers of this ratio, while
ttle loss of theoretical interest in using its numerical
Moreover it is not difficult to find out how many places
ls are necessary at the outset in order to secure a given
f places in the results.
exceptional precautions have been taken to avoid the

Hansen's results to the same system, so that these are also available for comparison. This comparison will appear in a following number of the *Monthly Notices*. Nearly all the differences Delaunay–Brown can be explained by slow convergence of the Delaunay series, and in most of the remaining cases the differences Hansen–Brown are very small. Unexplained disagreements between the new results and those of both the earlier theories only occurred in the cases of coefficients difficult to determine accurately by the latter methods, owing to the occurrence of very small divisors and the slowness of approximation proceeding along powers of the disturbing force.

Fifth, comparison of the new coefficients with those deduced from observation has at present only been possible to a limited extent, but in two cases—the mean movements of the perigee and node—it has been completed. The net result is very satisfactory. The differences in the annual motions of these two lines are less than three-tenths of a second of arc, and these are capable of being explained by reasonable suppositions concerning the figures of the Earth and Moon, the constants connected with these bodies not being yet known with sufficient accuracy. One of the most important coefficients—that of the principal parallactic inequality in longitude—appears to furnish a value for the solar parallax very near the mean of all the values obtained by other methods.

A few brief details about the amount of time and labour expended may not be uninteresting. From 1890 to 1895 certain classes of inequalities were calculated, but the work was only begun on a systematic plan, which involved a fresh computation of all inequalities previously found, at the beginning of 1896. Mr. Sterner began work for me in the autumn of 1897 and finished it in the spring of the present year,* though neither of us was by any means continuously engaged in calculation during that period. He spent on it, according to a carefully kept record, nearly three thousand hours, and I estimate my share as some five or six thousand hours, so that the calculations have probably occupied altogether about eight or nine thousand hours. There were about 13,000 multiplications of series made, containing some 400,000 separate products; the whole of the work required the writing of between four and five millions of digits and *plus* and *minus* signs.

Although the problem now completed constitutes by far the longer part of the whole, much remains to be done before it is advisable to proceed to the construction of tables. The problem solved is that of the Moon under the attractions of the Earth and Sun, the centre of mass of the Earth and Moon being supposed to move in a fixed elliptic orbit. There remains to be found the effect of the figures of the bodies—mainly that of the Earth—the effects of the differences of the actual motion of the

* Most of the expense has been met by grants from the Government Grant Committee of the Royal Society.

mass of the Earth and Moon from fixed elliptic motion,
e attractions of the planets ; and, the most difficult of
ffects of the direct attractions of the planets on the
There are many periodic coefficients, due to the last,
an one-tenth of a second of arc in magnitude, and the
bject needs a careful and extended investigation. An
to complete the problem by considering anew these
g sources of disturbance has been already started. The
s presented appear to arise much less from intricate
ns than in the construction of a satisfactory method
l give the assurance that no sensible terms have been
. If a moderate degree of success attends these efforts
be possible to discover whether, within the limits set
servations, the motion of the Moon shows effects which
traced to the direct operation of the Newtonian law of
n.

l College : 1904 *November* 18.

TABLE I.

Auxiliary Angles and their Epochs used for Short-period Analyses.

Angles.							Epochs at which the Angles pass through the Value Zero.
							Lunar Days.
${}_{80}A_3$,	${}_{80}A_5$,	${}_{80}A_8$,					0·5
${}_{74}A_2$,	${}_{74}A_3$,	${}_{74}A_5$,	${}_{74}A_6$,	${}_{74}A_8$,	${}_{74}A_{10}$,	${}_{74}A_{16}$	0·0
${}_{53}A_2$,	${}_{53}A_4$,	${}_{53}A_6$,	${}_{53}A_8$,	${}_{53}A_{10}$,			0·0
${}_{51}A_4$,							0·0
${}_{49}A_7$,	${}_{49}A_9$,						0·0
${}_{43}A_5$,							0·0
${}_{41}A_1$,	${}_{41}A_3$,	${}_{41}A_6$,					0·0
${}_{39}A_4$,							0·0
${}_{34}A_1$,	${}_{34}A_2$,						−1·5
${}_{31}A_1$,	${}_{31}A_2$,	${}_{31}A_3$,					0·0
${}_{29}A_4$,							0·0
${}_{28}A_5$,							0·0
${}_{27}A_3$,	${}_{27}A_4$,	${}_{27}A_6$,					0·0
${}_{23}A_1$,	${}_{23}A_4$,						0·0
${}_{22}A_1$,							0·0
D,	2D,	3D,	4D,	5D,			...

Table I. gives a list of the auxiliary angles; the mean motion of every angle is implied in its symbol; its definition is, therefore, completed by its epoch. The second column of the table gives the interval after the mean lunar noon of 1750 September $12^d\ 9^h$, at which the auxiliary angles took the value zero. The want of symmetry about the 34-day analysis is due to its having been performed about last May, before the complete scheme of analysis had been drawn up. Its epoch was chosen at haphazard. It will be seen that the strips that I have described in the paper quoted (vol. lxiv. May) have to be arranged in sixteen different ways (and in a seventeenth way for the D analysis), so as to bring the lines representing every 80th, every 74th, &c., day successively into juxtaposition. The sums of the errors for corresponding days are then easily formed. This stage occupies one computer about fifteen minutes for one analysis for one period. The present paper contains (counting the analyses for the Airy observations) about 1000 repetitions of this process. When such an angle as ${}_{49}A_9$ is necessary to the scheme it is clearly economical of labour to use ${}_{49}A_7$ in preference to ${}_7A_1$.

TABLE II.

Short-period Terms.

Argument.	Movement in One Lunar Day.	Auxiliary Angle.	Excess of Argument over Auxiliary Angle at T_0.	Excess of Argument over Auxiliary Angle in 400 Lunar Days $=2\theta$.
$-5g'+2\omega-2\omega'$	22°·175632	$_{80}A_5$	11°·46	−129°·7472
$-5g'+4\omega-4\omega'$	22·406154	"	264·08	− 37·5384
$-5g'+4\omega-4\omega'$	35·929074	$_{80}A_8$	243·85	− 28·3704
$-4g'+2\omega-4\omega'$	9·563141	$_{74}A_2$	160·81	− 66·6356
$-4g'+2\omega-2\omega'$	9·672858	"	293·67	− 22·7488
$-4g'+4\omega-4\omega'$	9·903380	"	186·29	+ 69·4600
$+g'-2\omega+2\omega'$	14·312544	$_{74}A_3$	118·05	−112·8204
$+g'-\omega+\omega'$	14·427805	"	64·36	− 66·7160
$+g'$	14·543066	"	10·67	− 20·6116
$+g'+\omega+\omega'$	14·768044	"	89·84	+ 69·3796
$-3g'+2\omega-2\omega'$	24·215924	$_{74}A_5$	304·34	− 43·3604
$-3g'+3\omega-3\omega'$	24·331185	"	250·65	+ 2·7440

Ref. No.	Argument.	Movement in One Lunar Day.	Auxiliary Angle.	Excess of Argument over Auxiliary Angle at T_0	Excess of Argument over Auxiliary Angle in 400 Lunar Days $= 2\theta$.
36	$5g$	67°·614600	$53A_{10}$	38°·05	−123°·9720
37	$5g+2\varpi$	67·954839	„	63·53	+ 12·1236
38	$2g+g'-\varpi+\varpi'$	27·950725	$51A_4$	109·13	−113·8268
39	$2g+g'$	28·065986	„	55·44	− 67·7224
40	$2g+g'+2\varpi$	28·406225	„	80·92	+ 68·3732
41	$4g-3g'+2\varpi-2\varpi'$	51·261764	$49A_7$	236·41	− 66·7236
42	$4g-3g'+4\varpi-4\varpi'$	51·492286	„	129·03	+ 25·4852
43	$4g-3g'+4\varpi-2\varpi'$	51·602003	„	261·89	+ 69·3720
44	$5g-2g'+2\varpi-2\varpi'$	65·804830	$49A_9$	319·50	−127·0484
45	$5g-2g'+4\varpi-2\varpi'$	66·145069	„	344·98	+ 9·0472
46	$3g+g'$	41·588906	$43A_5$	10·45	−108·6236
47	$3g+g'+2\varpi$	41·929145	„	35·93	+ 27·4720
48	$g-5g'+2\varpi-2\varpi'$	8·652712	$41A_1$	246·81	− 51·1104
49	$2g-g'$	26·025694	$41A_3$	240·76	−126·3080
50	$2g-g'+\varpi-\varpi'$	26·140955	„	187·07	− 80·2036
51	$2g-g'+2\varpi-2\varpi'$	26·256216	„	133·38	− 34·0992
52	$4g-2g'+2\varpi-2\varpi'$	52·281910	$41A_6$	14·14	−160·4072
53	$4g-2g'+4\varpi-2\varpi'$	52·622149	„	39·62	− 24·3116
54	$3g-4g'+2\varpi-2\varpi'$	36·718698	$39A_4$	115·37	− 81·7512
55	$3g-4g'+4\varpi-4\varpi'$	36·949220	„	7·99	+ 10·4576
56	$g-3g'-2\varpi'$	10·352765	$34A_1$	78·02	− 94·1880
57	$g-3g'+\varpi-3\varpi'$	10·468026	„	24·33	− 48·0836
58	$g-3g'+2\varpi-2\varpi'$	10·693004	„	103·50	+ 41·9076
59	$g-3g'+3\varpi-3\varpi'$	10·808265	„	49·81	+ 88·0120
60	$2g-6g'+4\varpi-4\varpi'$	21·386008	$34A_2$	207·00	+ 83·8152
61	$g-2g'-2\varpi'$	11·372911	$31A_1$	268·31	− 95·9968
62	$g-2g'$	11·482628	„	41·17	− 52·1100
63	$g-2g'+\varpi-\varpi'$	11·597889	„	347·48	− 6·0056
64	$g-2g'+2\varpi-2\varpi'$	11·713150	„	293·79	+ 40·0988
65	$2g-4g'+2\varpi-2\varpi'$	23·195778	$31A_2$	334·96	− 12·0112
66	$2g-4g'+3\varpi-3\varpi'$	23·311039	„	281·27	+ 34·0932
67	$2g-4g+4\varpi-4\varpi'$	23·426300	„	227·58	+ 80·1976
68	$3g-6g'+4\varpi-4\varpi'$	34·908928	$31A_3$	268·75	+ 28·0876
69	$3g-6g'+6\varpi-6\varpi'$	35·139450	„	161·37	+120·2964
70	$4g-5g'+4\varpi-4\varpi'$	49·451994	$29A_4$	18·78	− 81·2712
71	$5g-4g'+4\varpi-4\varpi'$	63·995060	$28A_5$	123·98	−116·2620
72	$5g-4g'+6\varpi-4\varpi'$	64·335299	„	149·46	+ 19·8336

Argument.	Movement in One Lunar Day.	Auxiliary Angle.	Excess of Argument over Auxiliary Angle at T_0.	Excess of Argument over Auxiliary Angle in 400 Lunar Days $=2\theta$.
$-g'$	39°548614	${}_{27}A_3$	335°17	−180°5544
$-g'+\omega-\omega'$	39·663875	„	281·48	−134·4500
$-g'+2\omega-2\omega'$	39·779136	„	227·79	− 88·3456
$-g'+2\omega$	39·888853	„	0·65	− 44·4588
$-g'+3\omega-\omega'$	40·004114	„	306·96	+ 1·6456
$-g'+2\omega-2\omega'$	53·302056	${}_{27}A_4$	0·89	− 12·5108
$-2g'+4\omega-2\omega'$	79·667989	${}_{27}A_6$	228·44	−132·8044
$+2g'-2\omega+2\omega'$	15·332690	${}_{23}A_1$	79·78	−127·7936
$+2g'$	15·563212	„	332·40	− 35·5848
$+2g'+2\omega'$	15·672929	„	105·26	+ 8·3020
$-6g'+6\omega-6\omega'$	62·185290	${}_{23}A_4$	29·27	−169·3624
$+3g'-2\omega+2\omega'$	16·352836	${}_{22}A_1$	304·12	− 4·3200
$-g'$	12·502774	D	53·69	− 46·1043

[redacted]

Ref. No.	Argument.	Movement in One Lunar Day.	Auxiliary Angle.	Excess of Argument over Auxiliary Angle	
				at T_0	in 400 Lunar Days $=2\theta$.
		°		°	°
107	$2D-g+3V-3E$	13·627542	$_{53}A_2$	322·69	+ 17·0543
108	$2D-E+J$	24·301919	$_{74}A_5$	286·99	− 8·9623
109	$2D-g+E-J$	12·647302	D	323·68	+ 11·7066
110	$2D-g-E+J$	10·778999	$_{34}A_1$	86·15	+ 76·3056
111	$g-2E+2J$	11·654618	$_{31}A_1$	6·45	+ 16·6859
112	$2D-g+2E-2J$	13·581453	$_{53}A_2$	222·95	− 1·3813
113	$g+2\varpi-3J+7^\circ$	13·495528	$_{53}A_2$	147·81	− 35·7513
114	$g-\Omega$	13·577730	$_{53}A_2$	262·53	− 2·8702
115	$g+\Omega$	13·468110	$_{53}A_2$	328·68	− 46·7184
116	$2g+2\omega+\Omega$	27·331269	$_{53}A_4$	289·78	+ 64·5829

TABLE III.

Terms of Periods Comparable with One Year.

Arg.	Unit.	Movement in 40 Lunar Days		Value at T_0	
		in Degrees.	in Units.	in Degrees.	in Units.
		°		°	
$4g'-2\omega+2\omega'$		See No. 123.			
$3g'+2\omega'$	$360\div\frac{17}{8}$	126·80619	$1-\frac{1}{8}\times0·011930$	145·2749	6·8602÷6
$3g'$		See No. 128.			
$3g'-2\omega+2\omega'$	$360\div\frac{19}{8}$	113·19663	$1-\frac{1}{8}\times0·025733$	119·7855	6·3220÷6
$2g'+2\omega'$	$360+\frac{21}{5}$	86·00036	$1+\frac{1}{5}\times0·016688$	141·1374	8·2330÷5
$2g'$		See No. 128.			
$2g'-\omega+\omega'$	$360\div\frac{14}{8}$	77·00123	$1-\frac{1}{3}\times0·005508$	61·9615	2·4096+3
$2E-2J$		See No. 130.			
$2g'-2\omega+2\omega'$		See No. 131.			
$2V-2E$		See No. 135.			
$g'+2\omega'$	360÷8	45·19453	1 + 0·004323	136·9999	3·0444
g'	360÷9	40·80583	1 + 0·020146	4·1375	0·1034
$2E-2M$	$360\div\frac{47}{5}$	38·22036	$1-\frac{1}{5}\times0·010120$	98·1768	12·8175÷5
$E-J$	$360+\frac{29}{3}$	37·36605	$1+\frac{1}{3}\times0·010043$	21·4980	1·7318÷3
$g'-\omega+\omega'$	360÷10	36·19540	1 + 0·005428	57·8240	1·6062
$3V-4E-2^\circ$	360+10	35·76947	1 − 0·006404	37·0854	1·0302
$E-2J+298^\circ$	$360+\frac{32}{3}$	33·92591	$1+\frac{1}{3}\times0·015636$	237·3525	21·0980÷3
$g'-2\omega+2\omega'$	$360+\frac{57}{5}$	31·58497	$1+\frac{1}{5}\times0·000954$	111·5105	17·6558÷5
$V-E$	360+14	·52522	1 − 0·007353	47·5763	1·8502

TABLE IV.

Terms of Periods Comparable with Ten Years.

Ref. No.	Arg.	Unit.	Movement in 200 Lunar Days		Value at T_0	
			in Degrees.	in Units.	in Degrees.	in Units.
136	2ω	$360 \div \frac{1}{3}^{\circ}$	$68^{\circ}.0478$	$1 + \frac{1}{3} \times 0.02435$	$25^{\circ}.4894$	$1.1329 \div 3$
137	$2V - 3E - 5^{\circ}$	$360 \div 7$	51.2212	$1 -$ 0.00403	346.5091	6.7377
138	$2\omega - 2\omega'$		See No. 140.			
139	$4M - 2E + 98^{\circ}$		See No. 142.			
140	$\omega - \omega'$	$360 \div 16$	23.0522	$1 +$ 0.02454	306.3135	13.6139
141	$J + 9^{\circ}$	$360 \div 21$	17.2007	$1 +$ 0.00337	91.1455	5.3168
142	$2M - E + 49^{\circ}$	$360 \div 28$	12.9292	$1 +$ 0.00560	54.4667	4.2363
143	$2\varpi - 2J$	$360 \div 31$	11.7222	$1 +$ 0.00941	287.3482	24.7439
144	$-\Omega$	$360 \div 33$	10.9620	$1 +$ 0.00485	326.9251	29.9681
145	$-2\varpi + 3J - 7^{\circ}$	$360 \div 66$	5.4785	$1 +$ 0.00439	147.7973	27.0962

Table II. gives a list of 116 short period terms. I selected for analysis those terms whose coefficients appeared from theory to exceed $0''.1$. The only use made of theory is to give the arguments. In all cases the coefficient is deduced from observation. The argument is in the second column of the table, the first column containing a reference number. The third column gives the mean motion of the argument in one lunar day, and the fourth column the auxiliary angle whose mean motion is nearly equal to that of the argument. The fifth column gives the excess of the argument over the auxiliary angle at T_0, or the middle of my forty-fourth period of analysis (the calendar date, which I never use, is given on vol. lxiv. p. 421); in the sixth column the excess of motion in 400 lunar days of the argument over the auxiliary angle is given. I call this excess 2θ. The order of Table II. is (i.) Solar; (ii.) *Venus*; (iii.) *Jupiter*; (iv.) figure of Earth terms; for the solar terms the order of the auxiliary angles is that of Table I.; when several terms have the same auxiliary angle the slowest term is put first. Table III. gives a list of terms of period comparable with one year, and Table IV. gives a list of terms of period comparable with ten years. The order is that of mean motion. The method of analysis is explained in vol. lxiv. June. The reference numbers run consecutively with Table II.

Table V.

Mean Error of Moon's Longitude for each of 890 Columns of Forty Lunar Days each in Tenth of a Second of Arc.

	Columns											
	1 to 40.	41 to 80.	81 to 120.	121 to 160.	161 to 200.	201 to 240.	241 to 280.	281 to 320.	321 to 360.	361 to 400.	401 to 440.	441 to 480.
1	+80	+13	−6	−40	−27	−35	−50	−66	−29	−71	−43	−18
2	+53	+4	+13	−23	+3	−49	−32	−45	−36	−50	+3	+2
3	+58	+3	+13	−10	−53	−3	−15	−18	−40	−21	−43	−2
4	+52	+13	+24	(−25)	−8	−27	−36	−41	−46	−40	+5	−7
5	+29	+15	−11	−26	−1	−21	−21	−32	−10	−52	−13	−11
6	+38	+10	−3	+21	−33	−33	−29	−50	−20	−51	+6	−25
7	+67	0	+8	−17	0	−46	−59	−36	−8	−60	+7	−18
8	+60	+12	+34	+27	−18	−25	−47	−45	−23	−55	−18	−35
9	+59	−5	+23	(+4)	−20	−20	−74	−31	−35	−56	−27	−31
10	+43	+3	+11	−17	−45	−34	−57	−39	−38	−79	−29	−30
11	+22	+37	+20	+45	−31	−32	−85	−34	−55	−64	+11	−3
12	+31	−20	+23	−5	−35	−40	−60	−28	−19	−40	−1	−13
13	+12	+9	+12	−2	−39	−59	−43	−45	−49	−51	−31	−20
14	+8	+21	+34	+3	−34	−44	(−62)	−40	−33	−51	−15	−24
15	+5	+3	+18	−10	−34	−34	(−63)	−52	−30	−70	−37	−25
16	+17	+34	+8	−4	−5	−23	(−61)	−55	−59	−67	−19	−18
17	+24	+12	+15	+13	−45	−45	−81	−31	−48	−37	−41	+29
18	+39	+6	+3	+15	−36	−31	−53	−13	−84	−65	−44	−5
19	+28	+26	+18	+14	−47	−35	−54	−20	−81	−61	−30	−12
20	+14	+5	−2	+11	−19	(−34)	−54	−3	−43	−52	+20	−7
21	+19	+11	+21	+10	+1	(−54)	−50	−33	−75	−47	−32	−12
22	+19	+15	−7	+12	−4	−69	−15	−22	−17	−57	−18	−34
23	+29	+6	−4	+3	0	−38	−24	−21	−46	−87	−26	−35
24	+47	+15	+6	−23	−17	−72	−45	−44	−34	−57	−31	−30
25	+16	−8	+19	−2	−14	−35	−47	−35	−40	−37	−36	−9
26	+51	+22	+2	+24	−28	−29	−55	−30	−51	−47	−21	−29
27	+7	+34	−5	+26	−39	−17	−44	−17	−27	−64	−14	−16
28	+6	+10	−14	+32	−17	−34	−21	−42	−75	−100	−6	−10
29	+8	−8	+49	−12	−21	−60	−25	−18	−47	−64	[−14]	−2
30	+36	+24	+42	−14	−4	−70	−35	−26	−29	−59	−14	−2
31	+25	+5	+30	−6	+3	−51	−35	−39	−39	−71	−4	−19
32	+30	−1	−1	−8	+4	−39	−51	−41	−48	−73	−23	+3
33	+25	+23	+5	−9	−14	−29	+8	−36	−55	−51	−12	−26
34	+34	+33	+5	−20	−19	−42	−13	−19	−57	−50	−4	−22
35	+31	0	+46	−8	+8	−16	−21	−26	−69	−25	−33	−8
36	+33	+41	+43	+11	−15	−32	−32	−27	−40	−32	−1	−1
37	+14	+4	+22	−3	−15	−31	−25	−16	−42	−52	−3	−20
38	+15	+14	+19	−22	−12	−51	−25	−23	−67	−55	−40	+12
39	+6	+30	+23	+32	−22	−48	−23	−47	−56	−61	+4	+14
40	+17	+17	+15	+2	−20	−42	−13	−44	65	−29	−28	−13

	Columns										
	481 to 520.	521 to 560.	561 to 600.	601 to 640.	641 to 680.	681 to 720.	721 to 760.	761 to 800.	801 to 840.	841 to 880.	881 to 890.
1	−14	−25	+23	+29	− 4	+12	+14	+14	+ 1	−20	−32
2	+14	−10	+12	+ 6	− 9	+15	+21	+14	+11	−26	−21
3	−29	−37	+19	+14	− 2	+ 2	+55	+ 5	+ 1	−22	−45
4	+ 3	−51	+29	+12	+15	−15	+46	−16	+ 1	−19	−32
5	0	−47	+29	+ 4	+10	−20	+31	+10	+18	− 4	−28
6	+ 8	−35	+18	+17	+26	+15	+53	+14	+ 9	+ 1	−30
7	+21	+ 7	+40	+44	+29	+ 3	+27	+14	+28	+ 1	−49
8	+ 7	−36	+ 3	+40	+17	+12	+ 4	+35	− 9	− 3	−36
9	−10	−21	− 9	+50	+32	+21	+15	+24	+ 3	− 4	−43
10	−24	−18	+ 7	+36	− 5	+ 3	+11	−15	− 4	−24	−38
11	−22	−20	+29	+24	+10	−44	+13	− 4	− 7	−15	...
12	−16	−16	+17	+ 9	+ 1	−32	+29	− 3	−27	− 9	...
13	−10	− 4	−21	+ 8	− 7	−34	+ 8	− 1	− 8	−31	...
14	−12	+ 1	− 4	+ 1	−11	−16	+13	+ 9	− 3	−20	...
15	− 5	− 2	− 2	+17	+15	+10	+30	+20	+ 2	− 6	...
16	− 9	+ 3	+15	+37	+ 1	+25	+25	+25	+ 3	− 4	...
17	− 4	−20	0	+38	+24	− 2	+ 7	+36	+34	0	...
18	+ 6	0	+18	+43	(+17)	+17	+24	+15	+19	− 7	...
19	−12	−22	+21	+ 5	(+17)	− 4	+45	+ 1	+11	−33	...
20	−10	−27	− 1	+10	+26	+14	+21	−22	−20	−45	...
21	+10	−26	0	+ 2	+11	− 3	+ 9	− 7	−26	−36	...
22	−21	−20	+ 7	− 6	+ 4	−26	+10	−18	−11	−32	...
23	−16	−17	+40	−11	− 3	− 9	0	+ 1	+10	−47	...
24	+ 7	−23	+10	+ 4	+ 9	−14	+35	−20	− 5	−40	...
25	+ 5	−18	+15	+32	+16	− 7	+27	+24	+12	−23	...
26	+ 1	0	+24	+19	+15	− 1	+22	+11	+ 1	−10	...
27	−13	0	+26	+12	+21	+22	+14	+13	+11	−27	...
28	− 3	− 5	+17	+19	+17	+31	+36	− 5	−15	−34	...
29	+ 2	−45	+27	+14	+ 1	+ 6	+17	+10	−13	−41	...
30	−33	+ 7	+15	− 5	−11	− 7	+24	−26	−18	−23	...
31	− 6	−12	+16	−10	− 5	+26	+22	+ 1	−21	−40	...
32	−19	−17	+ 9	0	+ 3	− 6	+10	−11	−13	−12	...
33	−10	−16	+28	− 2	− 4	+18	− 6	− 3	−35	−23	...
34	−22	−12	+10	+ 9	− 1	+16	+12	+ 6	−32	−26	...
35	− 4	−15	+ 8	+12	− 8	+ 3	+ 7	+25	−10	+ 2	...
36	−46	+ 4	+16	+34	−13	+34	− 9	+24	−31	−20	...
37	−49	−22	+13	+47	+20	+14	+ 7	+ 9	+13	−36	...
38	−26	+ 7	+12	+27	− 5	+34	+16	[+15]	−43	−46	...
39	−22	− 5	−20	−14	−20	+12	+25	+ 4	−19	−26	...
40	−32	− 2	+19	+18	+23	+13	+27	+22	−16	−30	...

TABLE VI.

Error of Moon's Longitude for each of 178 Half-Periods of 200 Lunar Days each in Tenths of a Second of Arc.

	1A to 8B.	9A to 16B.	17A to 24B.	25A to 32B.	33A to 40B.	41A to 48B.	49A to 56B.	57A to 64B.	65A to 72B.	73A to 80B.	81A to 88B.	89A and 89B.
	+28	−8	−2	+8	+11	+13	+12	+24	−9	+20	+10	+2
	+27	0	−8	−14	+18	+19	+17	+14	+9	+9	+9	−5
	−11	+9	−17	−21	+4	+15	+2	+3	−11	+7	−1	
	−3	−4	−12	−19	−22	+7	+9	+10	+4	+12	+17	
	−1	−3	+15	+8	−3	+2	+9	+11	−8	+4	+7	
	−5	+5	0	+8	−6	+13	+3	+19	−6	+11	+4	
	+4	+12	+21	+22	−15	+11	−1	+9	−18	0	−7	
	−8	+19	+8	+20	−15	+12	−24	+3	−14	+4	−4	
	−14	−26	+2	+5	−10	+17	−25	+8	−15	−2	+2	
	−20	+3	−3	+5	−23	−4	−12	+32	−3	+7	+14	
	−13	+8	−9	+4	−19	+5	0	+6	−38	0	+9	
2	−6	+12	−1	+20	−20	+19	−5	+21	−5	+7	+7	
3	−13	+6	−19	+13	−22	−3	−15	−4	−27	−6	−8	
4	−5	+17	−7	+17	−32	+9	−3	+4	−5	−1	+1	
5	−6	0	+2	+11	−21	+4	−9	−8	−4	+6	+11	
6	+3	+14	−4	+12	−13	+16	+1	+12	+6	+17	−1	

TABLE VII.

Mean Error of Moon's Longitude for each of 96 Half-Periods of 200 Lunar Days each in Tenths of a Second of Arc.

	86A to 93B.	94A to 101B.	102A to 109B.	110A to 117B.	118A to 125B.	126A to 133B.
1	+24	+4	+1	+26	−1	+13
2	+15	+2	+3	+17	−1	+9
3	+16	+2	+13	+18	−1	+6
4	+13	−13	+10	+17	−9	−3
5	+13	−3	+19	+9	+2	−2
6	+5	−15	+15	+5	0	0
7	+13	−12	+6	−9	0	−9

	A o 3B.	94A to 101B.	102A to 109B.	110A to 117B.	118A to 125B.
	− 1	−17	+ 9	−10	+ 6
	+ 4	−29	+ 7	−21	− 3
	+ 7	−23	+ 6	− 8	+14
	+ 5	−26	+18	−18	− 1
	+ 5	−17	+18	− 6	0
	+ 3	−18	+11	−19	− 1
	+ 5	−12	+20	−11	+ 8
	+ 7	− 5	+17	− 7	+18
5	+ 8	0	+14	− 3	+14

Tables V., VI., VII. give the data for the analy
bles III. and IV. Table V. gives for the Airy perio
1851 the mean error of the Moon's longitude for suc
tervals of forty lunar days ; the table is, in fact, similar
ne on vol. lxiv. p. 685 for the Hansen period 1847–1901. N
brackets have been supplied by interpolation
numbers in square brackets hav
iously erroneous observ
Hansen

TABLE VIII.

Mean Values for Periods 86 to 133 of the Errors of the Moon's Longitude Multiplied by co
Factors in Tenths of a Second of Arc.

Period.	80^s3.	80^c3.	80^s5.	80^c5.	80^s8.	80^c8.	74^s2.	74^c2.	74^s3.	74^c3.	74^s5.
86	− 1	− 3	− 1	− 1	+ 2	+ 1	+ 1	0	+ 5	+ 3	− 3
87	− 6	− 2	− 1	+ 1	+ 1	− 1	+ 3	0	+ 5	+ 7	0
88	+ 2	− 16	+ 2	− 2	− 1	− 1	+ 1	+ 1	0	− 2	− 3
89	+ 10	− 17	0	− 4	− 5	− 8	− 2	− 1	− 5	− 4	− 4
90	+ 13	− 5	− 1	− 1	− 5	+ 2	− 5	− 2	− 13	− 3	+ 1
91	+ 14	− 4	+ 1	+ 1	+ 2	0	+ 3	+ 5	− 1	− 1	− 1
92	+ 7	+ 10	+ 4	0	0	+ 3	− 4	+ 7	0	+ 4	− 1
93	− 5	+ 1	− 1	− 1	− 1	− 3	+ 1	+ 2	− 2	− 1	+ 1
94	− 3	+ 3	0	− 1	0	+ 4	− 1	− 1	+ 2	+ 2	− 6
95	− 1	− 6	+ 2	0	0	+ 2	− 3	− 1	+ 4	− 5	− 2
96	+ 14	− 8	− 1	− 1	− 1	− 1	0	− 2	+ 6	+ 2	− 4
97	+ 9	0	− 2	− 1	+ 2	− 2	+ 2	+ 5	+ 3	0	− 4
98	+ 9	+ 11	− 4	− 4	− 3	− 3	− 1	+ 1	+ 7	+ 7	− 3
99	+ 3	+ 11	+ 6	+ 1	− 2	− 2	0	− 7	+ 6	+ 3	− 3
100	− 8	0	− 1	+ 2	0	+ 3	− 4	+ 2	0	0	+ 3
101	− 2	0	+ 4	− 1	+ 2	− 1	− 1	+ 1	− 6	0	− 4
102	+ 1	− 2	+ 3	− 2	+ 1	− 2	0	+ 4	− 5	− 2	+ 5
103	+ 6	− 1	− 2	− 1	+ 1	+ 1	+ 2	0	+ 1	+ 4	− 1
104	+ 4	+ 5	+ 2	+ 1	+ 1	− 2	0	− 1	− 4	+ 7	− 1
105	0	+ 10	+ 1	0	− 1	− 3	+ 5	− 1	− 9	0	− 3
106	− 5	+ 7	− 3	+ 4	+ 1	+ 1	− 1	+ 3	− 4	− 6	− 1
107	− 7	− 2	+ 1	+ 1	0	− 3	0	+ 4	− 3	− 7	− 3
108	− 8	− 9	− 2	− 5	− 1	+ 1	+ 5	− 1	− 1	+ 1	0
109	− 3	− 4	+ 2	+ 3	− 1	+ 3	+ 3	− 3	+ 1	+ 5	0
110	+ 4	− 2	− 2	0	− 3	0	+ 1	+ 2	0	+ 2	+ 1
111	+ 5	− 9	+ 2	+ 3	− 1	− 1	+ 3	− 3	+ 6	− 4	− 9
112	0	0	− 1	0	− 2	− 3	− 3	+ 3	+ 5	0	+ 1
113	− 1	+ 1	0	+ 2	+ 1	0	+ 1	+ 1	+ 5	+ 1	− 2
114	+ 2	− 9	+ 3	0	− 1	− 2	− 3	+ 5	+ 5	+ 4	+ 2
115	+ 7	− 14	+ 1	− 1	− 2	− 4	+ 2	+ 1	+ 1	0	+ 5
116	+ 10	− 1	− 3	− 3	+ 1	− 3	− 2	+ 2	− 5	− 2	0
117	+ 7	+ 1	+ 2	− 1	+ 3	+ 4	0	0	− 6	− 1	+ 1
118	+ 10	+ 5	− 2	0	+ 2	− 1	− 2	+ 1	− 4	+ 4	+ 5
119	− 11	+ 3	+ 5	+ 2	+ 1	+ 3	+ 2	+ 5	+ 1	+ 5	+ 2
120	− 11	− 8	+ 5	− 2	− 2	− 1	− 2	+ 2	− 4	0	− 2
121	0	− 9	− 2	+ 2	+ 2	+ 1	− 1	− 4	− 3	− 3	− 1
122	+ 7	− 10	+ 5	− 2	− 2	+ 1	− 2	+ 2	− 5	− 7	+ 7
123	+ 6	− 5	0	− 2	− 3	+ 4	+ 5	+ 1	− 1	− 2	+ 3
124	+ 11	+ 3	+ 2	− 2	0	0	− 2	+ 2	+ 4	+ 1	− 1
125	0	+ 14	− 2	− 6	− 1	+ 2	0	− 2	+ 1	+ 6	− 2
126	− 7	+ 8	− 4	+ 1	− 2	− 3	+ 4	− 4	+ 1	+ 1	− 4
127	− 8	+ 3	− 1	− 1	+ 2	+ 4	0	0	+ 6	+ 1	− 7
128	− 3	− 5	0	+ 1	− 2	+ 5	0	+ 2	0	0	− 7
129	+ 8	− 1	+ 3	+ 1	− 2	0	0	+ 2	0	+ 6	0
130	+ 2	+ 2	+ 2	0	0	0	0	0	− 4	+ 2	− 5
131	+ 3	+ 6	− 4	− 3	+ 2	− 1	− 1	0	− 6	+ 2	− 3
132	− 4	+ 8	0	− 1	− 1	0	0	+ 1	− 2	− 3	− 3
133	− 2	− 3	+ 2	− 4	+ 1	+ 1	− 4	+ 2	0	− 9	− 5
Sums +	+ 174	+ 112	+ 60	+ 26	+ 28	+ 46	+ 44	+ 69	+ 75	+ 80	+ 37
Sums −	− 96	− 155	− 40	− 53	− 45	− 51	− 44	− 33	− 93	− 62	− 98
General Sum	+ 78	− 43	+ 20	− 27	− 17	− 5	0	+ 36	− 18	+ 18	− 61

$74^{s}8$	$74^{s}10$	$74^{c}10$	$74^{s}16$	$74^{c}16$	$53^{s}2$	$53^{c}2$	$53^{s}4$	$53^{c}4$
+ 3	− 1	+ 2	− 1	+ 1	− 1	− 3	− 1	+ 3
+ 2	0	+ 1	+ 5	0	− 4	+ 6	− 2	+ 8
+ 4	− 3	+ 3	+ 2	0	− 17	0	0	− 1
− 1	− 5	− 1	− 2	− 3	− 19	+ 3	− 4	+ 3
+ 7	0	+ 3	− 4	+ 3	− 14	+ 2	− 7	− 1
− 1	+ 2	0	0	0	− 13	+ 8	+ 3	− 4
− 1	+ 3	0	− 5	− 1	− 11	0	+ 4	− 6
− 1	− 2	+ 2	− 1	0	− 2	− 5	+ 2	0
− 3	+ 3	− 1	− 3	− 2	− 4	− 2	− 1	+ 2
− 5	+ 3	− 2	+ 4	+ 1	+ 2	− 8	− 2	+ 13
− 4	− 4	+ 3	− 2	+ 4	+ 11	− 11	− 4	+ 2
− 2	− 4	0	0	− 4	+ 7	− 7	0	+ 5
+ 1	0	+ 4	+ 3	+ 2	+ 12	− 7	− 6	+ 3
− 5	+ 2	0	+ 2	+ 6	+ 10	− 7	− 3	− 4
− 2	− 2	0	− 3	− 2	+ 7	+ 5	+ 2	− 4
− 2	0	+ 2	+ 1	+ 1	+ 3	+ 1	+ 7	+ 5
0	− 1	− 1	0	− 3	0	+ 2	0	+ 6
+ 5	− 2	+ 1	+ 2	+ 3	− 1	+ 6	+ 4	+ 5
0	+ 1	0	+ 2	− 2	− 5	+ 6	+ 1	+ 7
+ 5	+ 1	0	− 7	+ 3	− 8	+ 7	− 2	+ 10
+ 4	− 1	+ 5	− 1	− 1	− 6	+ 6	− 4	+ 3
+ 1	+ 2	− 4	− 3	− 8	− 8	+ 1	− 4	0
0	− 2	− 2	+ 1	0	− 11	+ 3	+ 3	− 6

Period.	53°6.	53°6.	53°8.	53°8.	53°10.	53°10.	51°4.	51°4.	49°7.	49°7.	49°9.
86	+ 3	+ 4	+ 3	0	0	− 2	0	+ 2	− 1	− 1	− 2
87	− 2	+ 2	+ 3	− 4	+ 2	− 3	− 2	− 2	+ 2	0	+ 1
88	− 2	0	+ 6	+ 2	+ 2	+ 3	0	− 2	− 4	− 3	− 4
89	0	− 4	+ 2	0	− 2	+ 4	+ 1	0	− 3	+ 1	− 1
90	− 5	0	+ 1	− 1	− 4	0	+ 3	0	+ 2	− 5	0
91	− 6	− 2	+ 1	+ 1	− 2	− 4	+ 5	− 3	− 2	− 2	− 5
92	− 5	+ 3	+ 4	+ 2	+ 1	+ 2	+ 3	+ 1	+ 5	− 3	+ 3
93	− 4	+ 1	0	+ 1	+ 2	− 1	+ 1	+ 1	− 2	− 1	− 2
94	0	− 1	− 4	− 2	− 2	− 1	+ 1	− 1	− 3	0	+ 2
95	− 6	− 3	+ 3	− 2	− 2	− 1	+ 4	0	− 2	0	+ 1
96	+ 3	− 1	+ 4	− 1	− 2	+ 5	0	+ 3	+ 1	+ 4	− 1
97	+ 2	− 1	+ 2	− 3	+ 1	+ 2	0	+ 2	0	+ 2	+ 2
98	+ 3	− 7	+ 1	+ 4	+ 2	− 2	− 7	+ 2	− 2	− 4	+ 4
99	+ 1	− 4	+ 1	+ 6	+ 1	− 1	− 4	+ 6	− 3	+ 1	− 2
100	− 1	− 1	0	− 5	0	+ 2	+ 2	+ 1	+ 1	+ 1	+ 4
101	− 2	− 3	+ 5	− 4	− 3	+ 2	− 3	− 3	+ 2	− 5	+ 1
102	+ 5	+ 1	+ 2	+ 2	+ 2	+ 1	− 1	+ 3	− 2	+ 1	0
103	+ 2	0	− 5	− 1	− 2	+ 2	− 1	− 4	− 1	− 4	− 4
104	− 4	− 5	0	− 7	− 3	0	− 1	− 1	+ 4	− 1	− 2
105	− 2	+ 2	+ 3	+ 3	− 1	+ 1	+ 4	+ 1	0	− 4	− 1
106	− 3	+ 3	+ 1	+ 4	− 3	− 2	+ 1	0	− 1	− 3	0
107	+ 4	0	− 1	0	+ 2	− 1	− 1	0	− 3	− 2	− 1
108	− 1	+ 1	− 1	− 1	+ 5	0	− 2	− 1	− 1	+ 1	0
109	− 1	0	+ 1	+ 2	− 2	+ 1	+ 3	+ 5	+ 5	+ 1	+ 2
110	− 8	0	− 3	+ 5	− 1	+ 2	− 4	− 1	+ 3	+ 3	− 1
111	− 3	+ 1	− 4	+ 1	0	− 6	− 5	+ 5	+ 6	+ 1	0
112	− 5	− 3	− 6	− 1	− 3	− 1	0	+ 3	− 1	+ 5	0
113	− 1	− 6	+ 2	− 2	− 2	− 1	− 5	− 2	− 4	+ 1	− 1
114	0	− 2	+ 4	− 1	+ 4	0	− 2	0	− 5	− 1	+ 3
115	− 2	+ 2	− 2	+ 4	− 6	+ 1	+ 2	− 1	− 3	− 6	+ 1
116	− 2	− 5	− 2	− 1	+ 2	0	− 1	− 3	0	− 2	+ 2
117	− 1	+ 2	+ 1	+ 3	− 1	− 2	− 4	− 1	+ 3	− 2	− 1
118	+ 2	− 2	+ 1	− 2	+ 1	− 2	+ 3	+ 2	+ 2	− 1	− 3
119	+ 2	− 2	+ 1	+ 7	+ 4	+ 2	+ 1	0	+ 3	− 4	− 2
120	0	+ 1	− 5	+ 2	0	− 2	+ 2	+ 2	+ 1	− 2	0
121	0	+ 2	+ 1	− 5	+ 2	− 2	0	− 1	+ 1	− 1	+ 2
122	− 2	− 2	+ 2	+ 7	0	0	− 4	+ 1	− 2	− 1	− 6
123	+ 2	− 3	− 3	+ 3	+ 1	− 2	0	0	0	+ 2	0
124	0	+ 3	− 1	− 3	+ 6	0	+ 1	− 4	0	− 1	+ 1
125	− 1	+ 5	+ 2	+ 6	+ 7	0	+ 2	+ 5	+ 5	+ 2	− 6
126	+ 3	0	+ 3	+ 3	− 2	− 1	− 3	+ 3	− 1	− 2	0
127	0	+ 3	− 4	+ 3	− 4	+ 3	− 2	0	− 6	− 3	+ 1
128	− 2	+ 1	− 2	0	0	− 1	0	− 3	− 1	0	+ 5
129	0	+ 2	+ 1	− 1	− 2	+ 1	+ 1	+ 1	− 2	+ 2	+ 3
130	− 2	− 2	+ 2	+ 1	+ 3	+ 3	− 3	0	+ 1	0	− 2
131	+ 3	0	+ 1	0	0	− 5	0	− 3	+ 5	0	+ 1
132	+ 1	+ 6	+ 4	+ 1	+ 2	− 2	+ 3	− 3	+ 2	− 1	− 2
133	− 6	0	− 1	+ 3	− 2	+ 1	− 1	0	+ 5	+ 1	+ 1
Sums +	+ 36	+ 45	+ 68	+ 76	+ 52	+ 38	+ 43	+ 49	+ 59	+ 29	+ 40
Sums −	− 79	− 59	− 44	− 47	− 51	− 45	− 56	− 39	− 55	− 65	− 49
General Sum	− 43	− 14	+ 24	+ 29	+ 1	− 7	− 13	+ 10	+ 4	− 36	− 9

41°1.	41'3.	41°3.	41'6.	41°6.	39'4.	39°4.	34'1.	34°1.
+ 2	− 4	− 4	+ 1	+ 5	− 2	+ 8	− 2	+ 1
+ 1	+ 1	+ 1	− 1	0	+ 4	− 2	+ 1	+ 1
− 3	+ 7	− 2	− 1	+ 1	− 1	0	− 6	+ 2
+ 1	+ 1	− 6	− 4	+ 3	+ 2	+ 3	− 4	− 3
− 2	− 4	+ 1	− 1	+ 1	+ 6	− 3	+ 1	+ 1
0	− 7	+ 6	0	+ 1	− 2	+ 1	+ 4	+ 4
+ 2	− 4	+ 5	+ 2	− 1	0	+ 1	+ 1	− 7
0	+ 1	+ 2	0	+ 1	+ 5	− 7	+ 3	− 5
− 4	− 3	− 4	− 2	0	− 2	0	+ 2	− 2
0	+ 2	− 4	− 3	+ 2	− 2	0	+ 1	+ 5
0	+ 3	+ 1	− 3	+ 1	− 6	− 2	+ 2	+ 3
− 4	+ 5	+ 1	− 1	0	− 1	0	+ 1	0
− 8	− 2	− 5	+ 1	+ 3	+ 2	+ 2	+ 6	+ 3
+ 5	−10	− 4	+ 1	+ 1	− 2	+ 3	+ 5	+ 2
− 6	− 6	− 5	− 2	0	0	+ 3	0	+ 1
+ 2	0	− 2	0	0	+ 3	− 2	− 2	+ 3
+ 1	+ 1	+ 1	0	+ 3	+ 5	0	− 5	+ 3
− 4	− 5	+ 2	+ 1	0	− 2	− 3	− 3	+ 3
− 2	− 2	+ 2	+ 2	+ 1	− 1	− 3	+ 2	+ 5
− 4	+ 4	0	− 3	− 2	− 2	+ 1	− 4	0
+ 1	+ 2	− 2	− 2	− 1	− 1	+ 2	− 3	+ 1
− 3	+ 5	− 1	+ 1	0	− 9	+ 5	− 2	0

Period.	$34^{s}2.$	$34^{c}2.$	$31^{s}1.$	$31^{c}1.$	$31^{s}2.$	$31^{c}2.$	$31^{s}3.$	$31^{c}3.$	$29^{s}4.$	$29^{c}4.$	28
86	− 2	+ 2	+ 1	− 2	+ 1	− 2	− 1	+ 3	+ 2	+ 5	−
87	− 2	− 4	− 2	− 1	+ 5	− 5	+ 3	0	0	+ 2	+
88	0	0	− 2	− 1	− 1	+ 1	0	− 4	− 1	− 1	+
89	− 2	+ 2	− 2	− 3	+ 2	0	0	+ 3	− 2	0	−
90	+ 1	0	− 3	+ 3	0	+ 1	− 5	+ 1	− 6	0	−
91	0	− 2	− 2	+ 2	− 2	+ 3	+ 1	+ 2	+ 3	− 3	
92	+ 2	− 3	+ 2	+ 1	+ 2	− 2	− 4	− 2	0	− 3	
93	− 1	0	0	+ 4	− 1	− 2	+ 3	+ 1	+ 2	− 2	
94	− 2	+ 1	− 4	+ 5	+ 1	− 2	− 3	− 2	− 2	− 2	+
95	− 4	0	− 4	+ 5	− 1	0	− 1	+ 1	+ 3	− 1	
96	+ 2	0	− 1	+ 8	+ 2	− 4	+ 2	− 1	− 1	+ 1	+
97	+ 1	+ 3	− 9	+ 4	− 1	− 2	− 5	+ 2	+ 2	− 1	+
98	− 4	+ 1	− 6	+ 2	+ 1	− 6	+ 2	− 3	− 2	0	+
99	− 4	0	− 9	− 1	+ 3	− 2	+ 4	+ 2	− 3	− 3	
100	+ 3	− 1	− 6	− 4	− 1	− 1	0	− 1	− 1	− 2	−
101	+ 4	− 3	+ 2	− 5	0	0	+ 4	− 1	+ 3	+ 2	+
102	− 2	+ 1	+ 2	− 4	0	+ 6	+ 2	+ 1	+ 2	− 3	−
103	0	+ 1	+ 6	− 1	+ 1	+ 2	+ 4	+ 1	− 2	− 5	−
104	+ 3	− 2	+ 4	− 3	− 1	− 2	+ 1	− 2	+ 1	− 1	−
105	+ 3	+ 1	− 3	+ 4	+ 4	+ 2	+ 4	+ 2	+ 4	− 2	−
106	0	0	− 4	− 1	+ 1	− 1	0	− 1	0	− 2	
107	+ 2	+ 2	+ 3	− 4	0	− 3	+ 3	0	− 2	− 2	+
108	− 2	+ 1	+ 1	− 5	+ 1	− 4	0	0	− 2	0	+
109	+ 1	− 1	+ 5	0	− 3	0	+ 1	− 3	− 1	0	
110	+ 4	+ 4	+ 1	0	− 1	− 6	0	+ 2	+ 1	− 1	+
111	0	0	+ 8	+ 7	+ 1	+ 3	+ 2	0	0	+ 1	+
112	+ 2	− 4	− 2	+ 4	+ 6	+ 2	− 4	− 2	0	+ 3	−
113	0	+ 2	− 2	0	− 2	0	0	+ 1	− 1	+ 1	−
114	+ 3	− 1	+ 3	+ 1	− 6	− 1	+ 1	+ 2	+ 4	− 4	+
115	+ 2	+ 2	− 2	0	− 6	− 3	+ 1	+ 2	+ 1	0	+
116	− 6	− 2	− 6	− 5	− 1	+ 2	− 1	+ 1	− 1	+ 8	+
117	0	0	− 3	+ 2	− 3	+ 5	+ 1	0	+ 1	− 1	+
118	0	+ 2	+ 2	− 2	+ 2	0	− 3	+ 1	+ 3	− 1	−
119	0	− 7	+ 2	+ 2	0	− 2	− 2	− 1	+ 2	− 1	−
120	+ 2	+ 6	+ 1	0	− 4	− 3	+ 4	0	+ 5	+ 1	+
121	+ 2	0	0	+ 5	− 1	− 1	+ 1	+ 2	0	− 1	+
122	− 2	0	− 7	− 2	+ 2	− 4	+ 2	− 2	0	+ 3	+
123	− 2	0	− 7	− 3	+ 3	+ 2	− 4	+ 2	− 3	+ 2	
124	0	− 2	− 10	− 1	+ 4	+ 4	+ 3	+ 1	0	+ 2	
125	+ 2	+ 8	− 4	− 4	0	0	+ 3	+ 5	+ 1	− 2	+
126	0	0	− 1	− 10	+ 1	− 2	+ 2	− 4	+ 1	− 2	+
127	+ 1	− 1	+ 6	− 6	+ 1	+ 2	− 2	− 3	− 1	0	+
128	− 2	0	+ 3	− 4	− 2	− 3	− 3	− 2	+ 2	0	+
129	0	+ 2	+ 2	+ 3	− 2	0	0	− 6	− 1	+ 1	
130	− 2	− 2	+ 4	+ 3	+ 1	0	+ 3	+ 1	− 2	+ 2	
131	+ 2	0	+ 5	+ 4	− 1	− 1	+ 4	− 1	+ 4	+ 2	
132	+ 3	+ 3	− 6	+ 7	− 1	0	+ 1	0	− 1	− 1	+
133	− 1	+ 3	− 6	+ 1	+ 4	+ 2	− 2	− 2	0	− 2	+
Sums +	+ 45	+ 47	+ 63	+ 77	+ 49	+ 37	+ 62	+ 39	+ 47	+ 36	+
Sums −	− 40	− 35	− 113	− 72	− 41	− 64	− 40	− 43	− 35	− 49	−
General Sum	+ 5	+ 12	− 50	+ 5	+ 8	− 27	+ 22	− 4	+ 12	− 13	+

$27^{c}4$.	$27^{s}6$.	$27^{c}6$.	$23^{s}1$.	$23^{c}1$.	$23^{s}4$.	$23^{c}4$.	$22^{s}1$.	$22^{c}1$.
− 5	− 5	− 2	+ 3	+ 3	+ 1	0	− 2	+ 3
+ 1	+ 4	− 3	− 5	− 1	+ 4	− 1	+ 5	+ 3
+ 2	+ 3	− 3	+ 4	+ 2	− 4	− 5	+ 3	+ 1
− 2	+ 2	− 3	+ 4	0	0	+ 2	− 1	− 1
+ 1	+ 3	+ 1	+ 3	− 6	− 3	+ 1	+ 2	0
+ 5	+ 5	+ 2	− 1	− 2	+ 1	− 5	− 1	0
+ 2	− 1	− 3	− 5	+ 1	− 1	+ 2	0	− 2
+ 3	− 2	− 3	− 4	− 1	+ 2	− 1	+ 3	− 3
− 7	+ 1	− 2	0	0	− 1	− 1	− 1	− 1
− 3	+ 1	+ 1	− 4	+ 3	+ 2	− 2	− 2	− 1
+ 3	− 2	− 5	− 4	+ 1	+ 1	0	− 2	− 1
+ 3	+ 1	+ 2	− 2	+ 1	+ 3	− 2	+ 2	+ 3
− 6	+ 6	0	+ 6	0	− 3	0	− 1	− 1
− 1	+ 1	0	− 3	− 5	+ 1	− 2	+ 1	+ 2
− 1	+ 1	− 2	− 2	+ 3	− 1	+ 4	− 2	− 4
− 1	+ 1	− 2	− 2	− 2	− 2	0	− 3	+ 1
+ 5	+ 1	− 1	− 3	− 3	+ 3	− 2	0	− 1
+ 1	+ 3	0	+ 3	− 2	0	+ 1	− 1	0
+ 5	+ 1	+ 2	+ 1	+ 2	− 3	+ 2	+ 1	0
+ 5	− 1	0	0	+ 4	0	− 6	+ 2	+ 3
− 3	0	+ 2	+ 2	− 2	− 1	+ 1	− 2	+ 2
0	+ 4	+ 5	+ 2	+ 1	+ 2	− 1	− 3	+ 4

TABLE IX.

[Residua]ls 1 to 89 of the Errors of the Moon's Longitude multiplied by [cert]ain Factors in Tenths of a Second of Arc.

$[5]3^s2$.	53^c2.	53^s4.	53^c4.	53^s6.	53^c6.	53^s8.	5[…]
14	+ 5	0	− 10	+ 2	− 7	− 6	−
11	+ 14	− 9	− 3	− 6	+ 9	− 8	−
18	+ 11	+ 8	+ 1	+ 6	+ 6	0	−
2	+ 7	− 5	+ 6	+ 2	+ 3	+ 7	−
0	+ 4	+ 12	− 4	− 8	+ 1	− 5	+
1	+ 15	− 1	+ 4	+ 2	0	− 1	+
7	+ 19	− 13	+ 9	+ 3	+ 5	− 2	+
15	+ 5	− 2	+ 3	+ 2	+ 5	+ 7	+
6	− 5	− 9	+ 8	− 9	+ 5	− 2	+
6	− 2	− 4	+ 6	+ 1	+ 7	+ 2	+
16	− 17	+ 10	− 6	− 12	− 9	+ 3	−
4	− 15	+ 13	+ 10	0	+ 9	− 1	−
15	− 12	+ 2	+ 11	+ 4	+ 7	+ 11	+
9	− 10	+ 4	+ 14	+ 4	0	+ 3	+
5	− 4	− 7	+ 17	0	− 1	− 1	+
7	− 7	0	+ 5	+ 2	− 18	+ 2	−
8	+ 3	− 4	+ 4	+ 10	− 6	+ 9	
1	+ 3	− 3	− 3	− 1	− 5	0	+
10	− 6	+ 7	+ 2	− 8	+ 8	− 11	+
5	− 11	+ 14	+ 9	− 5	+ 6	+ 5	−

Period.	53^s10.	53^c10.	sin g.	cos g.
1	+ 4	+ 7	− 2	+ 15
2	− 12	− 5	− 16	+ 8
3	+ 2	− 5	− 20	+ 8
4	+ 1	+ 4	− 5	− 5
5	+ 10	+ 3	0	− 4
6	− 2	+ 2	+ 7	− 13
7	− 6	− 9	+ 8	− 18
8	− 3	+ 2	0	− 16
9	− 1	+ 1	− 4	− 6
10	0	− 6	− 5	+ 4
11	+ 4	− 15	− 23	− 4
12	− 2	+ 4	+ 1	− 16
13	+ 4	− 4	− 11	− 16
14	− 2	+ 1	0	− 14
15	− 2	0	+ 2	− 6
16	− 1	+ 5	+ 7	+ 7
17	− 5	+ 1	− 6	+ 6
18	+ 3	− 3	− 3	− 2
19	+ 1	0	− 8	+ 9
20	− 11	− 4	+ 3	+ 12
21	− 3	− 8	− 4	+ 6
22	+ 7	− 2	0	− 12
23	+ 5	− 1	− 4	− 21
24	0	+ 7	+ 2	− 21
25	0	+ 11	+ 6	− 21
26	+ 3	+ 5	+ 12	− 4
27	+ 6	0	− 6	+ 19
28	+ 2	0	+ 1	− 4
29	− 1	− 2	− 1	+ 7
30	+ 9	+ 1	+ 1	+ 4
31	+ 4	− 2	− 7	+ 8
32	− 6	0	− 10	− 12
33	− 4	− 3	− 9	+ 11
34	+ 10	− 1	+ 15	− 10
35	+ 3	− 1	+ 1	− 2
36	− 1	+ 4	+ 2	+ 8
37	− 7	+ 2	− 5	+ 2
38	0	− 6	+ 3	+ 10
39	− 6	+ 7	+ 2	0
40	+ 3	+ 4	− 16	− 7
41	− 2	+ 5	− 21	− 25
42	− 8	− 3	− 11	− 15
43	− 4	+ 7	+ 7	− 11
44	− 4	+ 4	+ 6	− 11
45	+ 4	0	+ 16	− 1
46	+ 3	0	+ 13	+ 10
47	0	+ 1	+ 3	+ 32
48	− 3	− 6	− 16	+ 16
Sums +	+ 88	+ 88	+ 118	+ 202
Sums −	− 96	− 86	− 213	− 297
General Sum	− 8	+ 2	− 95	− 95

Period.	80^s3.	80^c3.	53^s2.	53^c2.
49	− 14	− 4	+ 13	0
50	− 8	− 3	+ 6	− 3
51	+ 5	0	+ 5	+ 7
52	+ 10	+ 9	+ 3	+ 16
53	− 7	+ 26	− 9	+ 22
54	− 9	+ 2	− 8	+ 4
55	− 7	− 12	− 14	0
56	+ 3	− 7	− 8	− 3
57	+ 18	− 17	− 25	− 5
58	+ 4	− 3	− 5	+ 1
59	+ 4	+ 2	− 6	− 1
60	− 5	+ 13	− 7	− 11
61	− 21	− 12	+ 14	− 20
62	− 6	− 12	+ 9	− 12
63	− 3	− 24	+ 9	− 24
64	+ 4	− 32	+ 4	− 35
65	+ 18	− 20	+ 1	− 26
66	+ 7	− 20	− 15	− 14
67	+ 12	− 7	− 11	− 8
68	− 2	− 14	− 8	+ 13
69	+ 1	− 21	− 3	+ 21
70	+ 7	− 16	− 1	+ 19
71	+ 23	− 16	+ 4	+ 29
72	+ 21	+ 3	− 1	+ 22
73	+ 8	+ 25	− 14	+ 21
74	+ 1	+ 5	0	+ 4
75	− 4	− 11	− 7	− 8
76	+ 6	− 27	− 16	− 22
77	+ 19	− 9	− 8	− 21
78	+ 20	+ 1	− 9	− 18
79	+ 27	+ 18	− 17	− 26
80	+ 14	+ 23	− 14	− 20
81	+ 16	+ 33	− 34	− 14
82	+ 7	+ 34	− 34	− 3
83	0	+ 19	− 17	+ 4
84	+ 7	+ 20	− 5	+ 19
85	+ 5	+ 26	+ 2	+ 24
86	− 1	+ 13	+ 7	+ 11
87	− 8	+ 12	+ 6	+ 12
88	− 14	+ 1	+ 2	+ 14
89	− 8	+ 1	+ 5	+ 4
Sums +	+ 267	+ 286	+ 90	+ 267
Sums −	− 117	− 287	− 296	− 294
General Sum	+ 150	− 1	− 206	− 27

53^s6.	53^c6.	53^s8.	53^c8.	53^s10.	53^c10.	sin *g*.	cos *g*.
+ 5	− 3	− 4	+ 4	− 6	− 3	− 13	− [illegible]
− 3	− 3	− 2	− 7	− 4	0	− 6	− [illegible]
+ 7	0	− 1	+ 6	+ 3	− 7	+ 3	− [illegible]
− 1	+ 9	+ 7	+ 1	− 6	0	+ 16	− [illegible]
− 4	+ 2	+ 4	− 6	+ 9	− 4	+ 19	+ [illegible]
− 7	0	+ 2	− 4	+ 7	− 2	− 2	+ [illegible]
+ 2	+ 4	+ 5	+ 4	− 3	+ 6	− 13	+ [illegible]
− 6	− 11	+ 5	− 6	+ 4	− 4	− 8	− [illegible]
+ 7	− 7	− 6	− 8	− 6	0	− 20	− [illegible]
+ 3	+ 1	+ 9	+ 1	+ 2	+ 1	− 4	− [illegible]
− 2	− 3	− 2	− 1	+ 9	+ 5	0	− [illegible]
+ 1	+ 3	+ 4	+ 1	+ 3	+ 7	+ 12	− [illegible]
+ 7	+ 7	+ 1	0	+ 1	+ 1	+ 8	+ [illegible]
+ 9	+ 10	− 5	− 7	− 7	+ 6	− 2	+ [illegible]
+ 3	+ 3	+ 2	− 3	− 1	− 4	− 7	+ [illegible]
− 3	+ 10	− 4	− 5	− 5	0	− 14	+ [illegible]
− 2	+ 6	− 6	+ 10	− 5	− 1	− 19	+ [illegible]
− 10	− 2	− 4	− 5	+ 1	+ 5	− 8	+ [illegible]
+ 3	− 4	− 1	− 3	+ 1	+ 2	− 9	+ [illegible]

It is clearly impossible to give the individual observations. Table VIII. (1847 to 1901) and Table IX. (1750 to 1851), however, give for each period of analysis the mean for each period of the product of each error by certain factors. In the column headed ${}_{m}s_{n}$ the factor is $2 \sin {}_{m}\mathrm{A}_{n}$; similarly for ${}_{m}c_{n}$ the factor is $2 \cos {}_{m}\mathrm{A}_{n}$. Columns headed sin D, cos D, sin 2D, cos 2D and μ, are copied from lxiv. p. 580, and the method of their calculation is there explained. Columns headed sin g, cos g, are found in this way. From Table II., No. 23, the values of $g-{}_{53}\mathrm{A}_2$ may be calculated for the middle of each period. Let $(g-{}_{53}\mathrm{A}_2)_0$ denote the value of $g-{}_{53}\mathrm{A}_2$ at the middle of a period; then

$$(g-{}_{53}\mathrm{A}_2)_0 = (g-{}_{53}\mathrm{A}_2) - k\theta$$

when 2θ is given in the last column of Table II. (in this instance $\theta = -12°4$), and k moves uniformly through a period of analysis from -1 to $+1$.

Now the columns headed sin g, cos g (Table IX.), are derived from those headed ${}_{53}s_2$, ${}_{53}c_2$, thus:

$$(\sin g) = ({}_{53}c_2) \sin (g-{}_{53}\mathrm{A}_2)_0 + ({}_{53}s_2) \cos (g-{}_{53}\mathrm{A}_2)_0$$
$$(\cos g) = ({}_{53}c_2) \cos (g-{}_{53}\mathrm{A}_2)_0 - ({}_{53}s_2) \sin (g-{}_{53}\mathrm{A}_2)_0$$

Referring to the definitions of the columns headed ${}_{53}s_2$ and ${}_{53}c_2$, it will be seen that the definition of the columns headed sin g and cos g are "mean values of the products of the errors by $2 \sin (g-k\theta)$ and $2 \cos (g-k\theta)$ respectively."

Now if θ were zero, and if we take means for a very large number of periods, then the means so arrived at are the coefficients of sin g and cos g in the errors, affected (i.) by purely accidental errors of observation, (ii.) by systematic errors (α) due to terms differing very slightly from g in mean motion, $g+\phi$ say, where ϕ is small. Systematic errors from this cause disappear if means are taken over a complete revolution of ϕ, and for solar terms the smallest value of ϕ is $\omega-\omega'$ whose period is 9 years; consequently in 50 years there is no systematic effect from any solar term (β) due to terms $g \pm \mathrm{D}$. This effect is due to the distribution of observations about full moon, and can be approximately allowed for by remarking that the mean value of cos D is $-\frac{1}{2}$ (γ) due to terms $g \pm \mathrm{D} + \phi$, a combination of causes (α) and (β) disappearing in process of time like (α).

Lastly, since θ is not zero, the results are diminished by the factor "mean value of $\cos k\theta$," o $\dfrac{\sin \theta}{\theta}$. Conversely, in forming an estimate of the error of the tabular term, the results arrived at must be increased by the factor $\dfrac{\theta}{\sin \theta}$.

Coefficients of sin g and cos g derived with the help of the auxiliary angle ${}_{53}\mathrm{A}_2$ have, by an oversight, not been printed in Table VIII. They have been compared with the last two

on lxiv. p. 415, which have been derived with the help
uxiliary angle ${}_{80}A_3$. There is an error of sign on that
sin g, period 98; otherwise there is a close agreement
the two sets of figures. As the arithmetic of the two
is absolutely different, the check afforded by the com-
s a very thorough one.

t the present time theory is defective, as regards long-
erms, it is probable that more theoretical short-period
ll from time to time be discovered. Table VIII. will in
bility suffice to compare such terms with observation.
ile Table VIII. is evidence that there are not any
n short-period terms with coefficients approaching to
l with arguments at all approximating to any of the
angles, with the possible exception of ${}_{53}A_2$, the angle
d with the mean anomaly.

'able X. I complete my analysis for the terms that I
ected. The first column contains the reference number.
nd column contains the argument associated with that
e number in Table II., III., or IV. In the case of
ms the argument is written in a second form, suggested
nsideration of systematic errors (β) mentioned above.
r of terms is arranged thus: first the solar terms were
groups, the members of the same group differing by

column has already been illustrated for the short-period terms with the mean anomaly as an example. For the terms of larger period see lxiv. June.

The fifth column gives the tabular coefficients (i.) Damoiseau's Tables modified by Airy and again by myself, see vol. lxiv. pp. 27–30, 571–573; (ii.) Hansen's Tables modified, see vol. lxiv. pp. 85, 414, 415.

The sixth column gives (i.) Hansen's theoretical coefficient, from the revised results in the "Darlegung" transformed by Professor Newcomb (*Astron. Papers Amer. Eph.*, vol. i.); (iii.) M. Radau's coefficient for planetary terms (Annales de l'Observatoire de Paris, *Mémoires*, xxi.), or in the case of four figure of Earth terms, Dr. G. W. Hill's coefficient (*Astron. Papers Amer. Eph.*, vol. iii.). These coefficients are marked R. H. respectively, to distinguish them from Hansen's solar terms.

The seventh column gives D_1 and D_2 from Professor Newcomb's "Transformation." They are Delaunay's coefficients before and after allowance for the higher terms not calculated.

The eighth column gives the observed coefficient. I only give them to $0''\cdot1$. From the third and fourth columns they can be deduced with a probable error of about $0''\cdot05$; but it did not seem worth while to apply probably erroneous corrections of less than $0''\cdot1$ to terms for which two independent theories in some cases agree to within $0''\cdot01$. Where the theoretical coefficients contain a secular term the observed coefficient in the eighth column is set down for the epoch 1875·0.

TABLE X.

"Apparent Observed" Tabular and Theoretical Coefficients of 149 *Terms in the Moon's Longitude.*

Reference No.	Argument. θ / $\sin\theta$	Apparent Tabular *minus* Observed Coefficients of sin (i.) periods 1–48 (ii.) „ 49–89 (iii.) „ 86–133	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	D_1. D_2.	Concluded Observed Coefficient
		''	''	''	''	''	'
109	$2D-g+E-J$	...	...	0·00	...	...	...
	1·0	(iii.) −0·22	+0·04	0·00	+0·10R	...	+0·
86	$g-g'+\omega-\omega'$	...	...	−124·68	−125·43	−125·49	...
	D	...	...	...	...	−125·98	...
	1·0	(iii.) 0·00	−0·14	−124·90	...	...	−124·
91	$2g-2g'+2\omega-2\omega'$	...	...	+2370·10	+2369·75	+2369·74	...
	2D	...	...	...	...	+2369·74	...
	1·0	(iii.) −0·04	+0·05	+2370·14	...	...	+2370·
5	$3g-3g'+3\omega-3\omega'$	...	...	+0·53	+0·41	+0·57	...
	3D	...	...	...	...	+0·54	...
	1·0	(iii.) −0·09	+0·01	+0·42	...	...	+0·

ent Tabular *minus* ved Coefficients of		Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients.		Conclu Observ Coeffici
sin periods " "	cos 1– 48 49– 89 86–133		Hansen. Radau (R). Hill (H).	D_1. D_2.	
"	"	"	"	"	
...	...	+ 13·94	+ 13·90	+ 13·89	...
...	...	...	...	+ 13·98	...
+0·09	−0·05	+ 13·90	...	...	+ 1
...	...	...	+ 0·01	+ 0·02	...
...	...	...	...	...	...
+0·08	−0·02	...	...	...	...
...	...	...	− 0·01	...	...
...	...	...	...	...	...
0·00	+0·03	...	...	...	...
...	...	− 0·90	− 0·64	− 0·83	...
...	...	...	...	− 0·83	...
−0·01	−0·05	− 0·64	...	...	−

Reference No.	Argument. θ / $\sin\theta$	Apparent Tabular *minus* Observed Coefficients of sin (i.) periods 1–48, (ii.) „ 49–89, (iii.) „ 86–133	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	Theoretical Coefficients. D_1. D_2.	Concluded Observed Coefficients.
		″	″	″	″	″	″
100	$5g-5g'+4\varpi-4\varpi'$	...	...	0·00	+ 0·29	+ 0·20	...
	$5D-\varpi+\varpi'$	...	...	...	...	...	...
	1·0	(iii.) +0·08	−0·02	+ 0·29	...	...	+ 0·2
97	$3g-3g'+4\varpi-2\varpi'$	...	...	− 0·73	− 0·43	− 0·43	...
	$3D+\varpi+\varpi'$	...	...	...	...	− 0·43	...
	1·1	(iii.) +0·07	0·00	− 0·39	...	...	− 0·4
...	$3g-3g'+2\varpi-4\varpi'$	...	...	...	...	...	...
	$3D-\varpi-\varpi'$	...	...	...	...	...	...
	1·1	(iii.) +0·02	+0·02	...	...	...	...
...	$2g-2g'+4\varpi-4\varpi'$	...	...	...	− 0·03	− 0·01	...
	$2D+2\varpi-2\varpi'$	...	...	...	...	...	...
	1·1	(iii.) +0·02	−0·09	...	...	...	...
138	$2\varpi-2\varpi'$	(i.) −0·07	−0·29	0·00	− 0·23	− 0·16	...
		(ii.) +0·26	+0·05	...	...	...	...
	1·0	(iii.) −0·06	−0·01	− 0·27	...	...	− 0·2
89	$2g-2g'$	...	...	0·00	+ 0·19	+ 0·16	...
	$2D-2\varpi+2\varpi'$	...	...	...	...	...	...
	1·1	(iii.) 0·00	−0·01	+ 0·19	...	...	+ 0·2
99	$4g-4g'+6\varpi-4\varpi'$	...	...	0·00	− 0·17	− 0·14	...
	$4D+2\varpi$	...	...	...	...	...	...
	1·3	(iii.) −0·04	+0·05	− 0·15	...	...	− 0·1
93	$2g-2g'+4\varpi-2\varpi'$	...	...	− 0·54	− 0·54	− 0·54	...
	$2D+2\varpi$	...	...	...	...	− 0·53	...
	1·3	(iii.) +0·07	0·00	− 0·54	...	...	− 0·6
136	2ϖ	(i.) −0·39	+0·30	+ 1·10	+ 1·09	+ 1·39	...
		(ii.) −0·51	+0·05	...	...	+ 1·38	...
	1·1	(iii.) −0·15	+0·06	+ 1·25	...	...	+ 1·4
88	$2g-2g'-2\varpi'$	...	...	− 0·50	− 0·43	− 0·45	...
	$2D-2\varpi$	...	...	...	...	− 0·45	...
	1·3	(iii.) 0·00	−0·06	− 0·43	...	...	− 0·4

ent Tabular *minus* ved Coefficients of sin periods	cos 1– 48, 49– 89, 86–133	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	D₁. D₂.	Conclud Observe Coefficie
″	″	″	″	″	
...	...	...	− 0·01	− 0·01	...
...	...	...	...	...	...
−0·02	+0·08	...	...	...	...
...	...	+ 1·16	+ 1·18	+ 1·11	...
...	...	...	...	+ 1·15	...
−0·03	+0·04	+ 1·18	...	...	+ 1
...	...	+ 9·60	+ 9·72	+ 9·59	...
...	...	...	...	+ 9·71	...
+0·02	−0·05	+ 9·72	...	...	+ 9
+0·26	−0·04	0·00	− 0·38	− 0·26	...
+0·29	+0·01	...	...	...	...
−0·03	+0·02	− 0·38	...	...	− 0

Reference No.	Argument. $\frac{\theta}{\sin\theta}$.	Apparent Tabular *minus* Observed Coefficients of: (i.) periods 1– 48; (ii.) „ 49– 89; (iii.) „ 86–133	sin	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (B). Hill (H).	Theoretical Coefficients. D_1. D_2.	Concluded Observed Coefficients.
			″	″	″	″	″	″
113	$g+2\varpi-3J+7°$	(i.)	+0·13	−0·02	+ 0·32	...	...	...
		(ii.)	−0·17	−0·03	...	...	...	...
	1·0	(iii.)	−0·10	−0·13	+ 0·32	+ 0·32R	...	+ 0·4
132	$3V-4E-2°$	(i.) (ii.)	+0·16	+0·27	0·00	...	...	...
					...	...	...	...
	1·0	(iii.)	+0·10	+0·08	0·00	− 0·18R	...	− 0·1
131	$g'-\varpi+\varpi'$	(i.) (ii.)	+0·17	−0·23	+ 18·60	+ 18·70	+ 18·35	...
					...	...	+ 18·76	...
	1·0	(iii.)	−0·08	+0·32	+ 18·60	...	...	+ 18·6
64	$g-2g'+2\varpi-2\varpi'$		...	...	+ 4586·34	+ 4586·56	+ 4586·24	...
	$D-g'+\varpi-\varpi'$		...	...	...	...	+ 4586·44	...
	1·0	(iii.)	+0·03	−0·31	+ 4586·44	...	...	+ 4586·4
12	$2g-3g'+3\varpi-3\varpi'$		...	...	− 3·00	− 3·23	− 2·98	...
	$2D-g'+\varpi-\varpi'$		...	...	...	...	− 3·12	..
	1·0	(iii.)	−0·06	+0·14	− 3·22	...	...	− 3·2
55	$3g-4g'+4\varpi-4\varpi'$		...	...	+ 38·46	+ 38·43	+ 38·31	...
	$3D-g'+\varpi-\varpi'$		...	...	...	...	+ 38·48	...
	1·0	(iii.)	−0·01	0·00	+ 38·43	...	...	+ 38·4
108	$2D-E+J$		...	...	0·00	...	...	...
	1·0	(iii.)	+0·23	−0·08	0·00	− 0·18R	...	− 0·2
83	$5g-6g'+6\varpi-6\varpi'$		...	...	0·00	+ 0·40	+ 0·26	...
	$5D-g'+\varpi-\varpi'$		...	...	...	...	...	...
	1·5	(iii.)	−0·06	−0·02	+ 0·40	...	...	+ 0·4
42	$4g-3g'+4\varpi-4\varpi'$		...	...	− 0·20	− 0·29	− 0·29	...
	$4D+g'$		...	...	...	...	− 0·30	...
	1·0	(iii.)	+0·04	+0·13	− 0·29	...	...	− 0·3
17	$3g-2g'+3\varpi-3\varpi'$		...	...	0·00	+ 0·15	+ 0·14	...
	$3D+g'$		...	...	...	...	...	...
	1·0	(iii.)	−0·20	−0·20	+ 0·15	...	...	+ 0·3

nt Tabular *minus* ed Coefficients of		Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients.		Conclud Observ Coefficie
in	cos		Hansen. Radau (R). Hill (H).	D_1. D_2.	
periods	1– 48				
"	49– 89				
"	86–133				
"	"	"	"	"	
...	...	− 24·48	− 24·45	− 24·60	...
...	...	...	...	− 24·50	...
−0·17	+0·02	− 24·45 + 0·06T	...	...	− 2
+0·27	−0·04	+ 17·90	+ 18·09	+ 18·08	...
+0·89	+0·02	...	...	+ 18·08	...
+0·70	+0·29	+ 18·17	...	...	+ 1
+0·58	+0·02	0·00	...	...	...
+0·90	−0·30	...	...	...	...
−0·39	−0·27	− 0·68	− 0·68R	...	−
		− 669·63 + 1·63T	− 669·85	− 669·57	...
−0·17	−0·10	...	...	− 669·76	...

Reference No.	Argument. $\frac{\theta}{\sin\theta}$.	Apparent Tabular *minus* Observed Coefficients of sin (i.) periods 1–48, (ii.) " 49–89, (iii.) " 86–133	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	D₁. D₂.	Concluded Observed Coefficients.
		"	"	"	"	"	"
25	$g+2\omega-2\omega'$	(i.) 0·00	−0·15	− 2·45	− 2·54	− 2·22	...
	$D+g'+\omega-\omega'$	(ii.) +0·06	+0·12	...	...	− 2·35	...
	1·1	(iii.) −0·06	−0·01	− 2·49	...	...	− 2·4
62	$g-2g'$	...	...	+ 2·59	+ 2·59	+ 2·49	...
	$D-g'-\omega+\omega'$	...	...	...	...	+ 2·59	...
	1·0	(iii.) +0·05	−0·04	+ 2·57	...	...	+ 2·5
54	$3g-4g'+2\omega-2\omega'$	...	...	+ 0·74	+ 0·76	+ 0·68	...
	$3D-g'-\omega+\omega'$	...	...	...	...	+ 0·72	...
	1·1	(iii.) +0·03	−0·04	+ 0·76	...	...	+ 0·7
72	$5g-4g'+6\omega-4\omega'$	...	...	0·00	− 0·20	− 0·16	...
	$5D+g'+\omega+\omega'$	...	...	...	...	...	...
	1·0	(iii.) +0·03	−0·02	− 0·20	...	...	− 0·2
18	$3g-2g'+4\omega-2\omega'$	...	...	− 9·40	− 9·37	− 9·34	...
	$3D+g'+\omega+\omega'$	...	...	...	...	− 9·39	...
	1·1	(iii.) +0·03	−0·05	− 9·37	...	...	− 9·4
26	$g+2\omega$	(i.) +0·08	−0·08	− 39·56	− 39·58	− 39·54	...
	$D+g'+\omega+\omega'$	(ii.) +0·01	−0·32	...	...	− 39·54	...
	1·2	(iii.) +0·14	−0·05	− 39·28	...	...	− 39·5
61	$g-2g'-2\omega'$	...	...	− 6·20	− 6·36	− 6·37	...
	$D-g'-\omega-\omega'$	...	...	...	...	− 6·37	...
	1·1	(iii.) +0·07	+0·05	− 6·44	...	...	− 6·5
73	$3g-g'$	...	...	+ 0·40	+ 0·67	+ 0·63	...
	$3D+2g'-3\omega+3\omega'$	..	...	...	...	+ 0·66	...
	1·6	(iii.) −0·03	+0·02	+ 0·67	...	...	+ 0·7
7	$g+g'-2\omega+2\omega'$	...	...	0·00	− 0·18	− 0·07	...
	$D+2g'-3\omega+3\omega'$	...	...	...	...	...	...
	1·2	(iii.) −0·02	+0·01	− 0·12	...	...	− 0·1
21	$6g-4g'+4\omega-4\omega'$	...	...	0·00	+ 0·22	+ 0·18	...
	$6D+2g'-2\omega+2\omega'$	...	...	...	...	+ 0·20	...
	1·2	(iii.) −0·05	+0·04	+ 0·17	...	...	+ 0·2

ent Tabular *minus* ved Coefficients of sin periods	cos 1– 48, 49– 89, 86–133	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	D$_1$. D$_2$.	Conclude Observed Coefficien
"	"	"	"	"	
...	...	+ 14·10	+ 14·38	+ 14·40	...
...	...	...	...	+ 14·40	...
+0·01	+0·01	+ 14·37	...	...	+ 14
...	...	− 0·40	− 0·59	− 0·57	...
...	...	...	...	− 0·60	...
−0·07	+0·06	− 0·59	...	...	− 0
+0·15	−0·04	+ 769·04	+ 769·06	+ 769·12	...
+0·24	+0·08	...	...	+ 769·06	...
−0·01	−0·08	+ 769·06	...	...	+ 769
...	...	+ 1·58	+ 1·78	+ 1·50	...
...	...	...	...	+ 1·59	...

Refer-ence No.	Argument. / $\frac{\theta}{\sin\theta}$.	Apparent Tabular *minus* Observed Coefficients of (i.) periods 1–48, (ii.) „ 49–89, (iii.) „ 86–133	sin	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	Theoretical Coefficients. D_1. D_2.	Concluded Observed Coefficients.
28	$2g+\varpi-\varpi'$	(i.)	−0·32″	+0·10″	+1·00″	+1·27″	+1·22″	...″
	$2D+2g'-\varpi+\varpi'$	(ii.)	−0·27	+0·24	...	...	+1·21	...
	1·0	(iii.)	−0·04	+0·21	+1·28	...	...	+1·
9	$g+g'$		...	...	−109·90	−109·92	−109·79	...
	$D+2g'-\varpi+\varpi'$		...	...	...	...	−109·85	...
	1·0	(iii.)	+0·10	−0·04	−109·95 +0·18T	...	...	−109·9
123	$2g'-\varpi+\varpi'$	(i.) (ii.)	−0·05	−0·08	0·00	+0·17	+0·14	...
					...	...	+0·14	...
	1·1	(iii.)	+0·09	−0·08	+0·15	...	...	+0·1
58	$g-3g'+2\varpi-2\varpi'$		...	...	+206·40	+206·46	+206·54	...
	$D-2g'+\varpi-\varpi'$		...	...	...	...	+206·34	...
	1·0	(iii.)	+0·05	+0·10	+206·49 −0·49T	...	...	+206·1
66	$2g-4g'+3\varpi-3\varpi'$		...	...	0·00	−0·23	−0·18	...
	$2D-2g'+\varpi-\varpi'$		...	...	...	...	...	...
	1·0	(iii.)	+0·08	−0·06	−0·23	...	...	−0·3
3	$3g-5g'+4\varpi-4\varpi'$		...	...	+4·38	+4·41	+4·28	...
	$3D-2g'+\varpi-\varpi'$		...	...	...	...	+4·34	...
	1·0	(iii.)	−0·02	+0·01	+4·40	...	...	+4·4
76	$3g-g'+2\varpi$		...	...	0·00	−0·30	−0·28	...
	$3D+2g'-\varpi+3\varpi'$		...	...	...	...	...	...
	1·0	(iii.)	+0·10	+0·15	−0·30	...	...	−0·4
29	$2g+2\varpi-2\varpi'$	(i.)	−0·16	+0·10	0·00	−0·19	−0·15	...
	$2D+2g'$	(ii.)	+0·32	−0·34	...	...	−0·15	...
	1·0	(iii.)	+0·20	−0·32	−0·19	...	...	−0·2
122	$2g'$	(i.) (ii.)	−0·13	−0·08	−7·50	−7·51	−7·49	...
					...	...	−7·46	...
	1·1	(iii.)	+0·05	−0·04	−7·49	...	...	−7·5
65	$2g-4g'+2\varpi-2\varpi'$		...	...	+7·80	+8·13	+8·06	...
	$2D-2g'$		...	...	...	...	+8·06	...
	1·0	(iii.)	+0·01	−0·02	+8·12	...	...	+8·1

nt Tabular *minus* ved Coefficients of: in periods	cos 1– 48 / 49– 89 / 86–133	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	D_1. D_2.	Concluded Observed Coefficients.
"	"	"	"	"	"
...	...	0·00	+ 0·15	+ 0·10	...
...	...	...	...	...	...
−0·06	+0·03	+ 0·15	...	...	+ 0·2[illegible]
...	...	− 5·74	− 5·74	− 5·73	...
...	...	...	...	− 5·73	...
+0·08	+0·02	− 5·75	...	...	− 5·8[illegible]
...	...	0·00	+ 0·25	+ 0·24	...
...	...	...	...	...	...
−0·07	+0·06	+ 0·24	...	...	+ 0·3[illegible]
+0·10	0·00	− 411·62	− 411·60	− 411·63	...
−0·06	−0·04	...	...	− 411·63	...
+0·01	+0·11	− 411·60	...	...	− 411·6[illegible]

Reference No.	Argument. $\frac{\theta}{\sin\theta}$.	Apparent Tabular *minus* Observed Coefficients of sin (i.) periods 1–48, (ii.) „ 49–89, (iii.) „ 86–133	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	D_1. D_2.	Concluded Observed Coefficients.
31	$3g$	(i.) +0″·05	−0″·03	+ 36″·12	+ 36″·13	+ 36″·16	...″
	$3D+3g'-3\varpi+3\varpi'$	(ii.) +0·09	+0·06	...	...	+ 36·12	...
	1·1	(iii.) −0·09	−0·08	+ 36·13	...	...	+ 36·2
38	$2g+g'-\varpi+\varpi'$	...	...	0·00	+ 0·12	+ 0·09	...
	$2D+3g'-3\varpi+3\varpi'$	...	...	...	...	...	...
	1·2	(iii.) −0·01	+0·10	+ 0·12	...	...	+ 0·1
80	$g+2g'-2\varpi+2\varpi'$	...	...	− 13·24	− 13·19	− 13·15	...
	$D+3g'-3\varpi+3\varpi'$	...	...	...	...	− 13·32	...
	1·2	(iii.) +0·04	−0·07	− 13·20	...	...	− 13·2
6	$g-4g'+4\varpi-4\varpi'$	...	...	+ 1·10	+ 1·18	+ 0·96	...
	$D-3g'+3\varpi-3\varpi'$	...	...	...	...	+ 1·08	...
	1·1	(iii.) −0·07	+0·02	+ 1·18	...	...	+ 1·2
69	$3g-6g'+6\varpi-6\varpi'$	...	...	0·00	+ 0·29	+ 0·20	...
	$3D-3g'+3\varpi-3\varpi'$	...	...	...	...	...	...
	1·2	(iii.) −0·01	+0·04	+ 0·29	...	...	+ 0·3
78	$4g-g'+2\varpi-2\varpi'$	...	...	0·00	− 0·29	− 0·27	...
	$4D+3g'-2\varpi+2\varpi'$	...	...	...	...	...	...
	1·0	(iii.) +0·03	+0·04	− 0·29	...	...	− 0·3
39	$2g+g'$	...	...	− 7·68	− 7·67	− 7·62	...
	$2D+3g'-2\omega+2\omega'$	...	...	...	...	− 7·69	...
	1·1	(iii.) −0·02	+0·01	− 7·67	...	...	− 7·7
120	$3g'-2\omega+2\omega'$	(i.), (ii.) −0·03	−0·07	− 8·66	− 8·66	− 8·66	...
				...	...	− 8·66	...
	1·2	(iii.) 0·00	−0·01	− 8·69	...	...	− 8·7
2	$2g-5g'+4\varpi-4\varpi'$	...	...	+ 2·75	+ 2·75	+ 2·69	...
	$2D-3g'+2\varpi-2\varpi'$	...	...	...	...	+ 2·75	...
	1·0	(iii.) −0·04	+0·07	+ 2·75	...	...	+ 2·8
81	$g+2g'$	...	...	− 1·20	− 1·18	− 1·16	...
	$D+3g'-\varpi+\varpi'$	...	...	...	...	− 1·16	...
	1·0	(iii.) −0·11	+0·01	− 1·18	...	...	− 1·1

nt Tabular *minus* ed Coefficients of in periods " "	cos 1– 48 49– 89 86–133	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	D₁. D₂.	Conclud Observ Coefficie
"	"	"	"	"	
...	...	+ 7·50	+ 7·44	+ 7·50	...
...	...	...	...	+ 7·50	...
+0·01	+0·05	+ 7·42	...	...	+
...	...	0·00	+ 0·31	+ 0·22	...
...	...	...	...	...	...
0·00	+0·03	+ 0·31	...	...	+
...	...	− 1·00	− 0·99	− 0·98	...
...	...	...	...	− 1·00	...
−0·03	−0·03	− 0·99	...	...	−
+0·25	0·00	− 45·20	− 45·09	− 45·12	...
−0·05	+0·31	...	...	− 45·12	...
−0·10	−0·02	− 45·08	...	...	− 4

Reference No.	Argument. $\frac{\theta}{\sin\theta}$.	Apparent Tabular *minus* Observed Coefficients of sin (i.) periods 1– 48, (ii.) " 49– 89, (iii.) " 86–133	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.		Theoretical Coefficients. Hansen. Radau (R). Hill (H).		D_1. D_2.		Concluded Observed Coefficients.	
33	$4g$	(i.) −0″·14	+0″·03	+	2″·00	+	1″·94	+	1″·96	...	″
	$4D + 4g' - 4\varpi + 4\varpi'$	(ii.) +0·09	−0·07		...		...	+	1·94	...	
	1·1	(iii.) +0·06	0·00	+	1·93		...		...	+	1·9
14	$2g + 2g' - 2\varpi + 2\varpi'$	...	...	−	0·90	−	0·95	−	0·91	...	
	$2D + 4g' - 4\varpi + 4\varpi'$	...	...		...		...	−	1·00	...	
	1·3	(iii.) −0·01	+0·05	−	0·95		...		...	−	0·9
46	$3g + g'$	...	...	−	0·40	−	0·55	−	0·52	...	
	$3D + 4g' - 3\varpi + 3\varpi'$	...	...		...		...	−	0·56	...	
	1·2	(iii.) +0·06	+0·01	−	0·55		...		...	−	0·6
84	$g + 3g' - 2\varpi + 2\varpi'$	...	...	−	0·30	−	0·48	−	0·49	...	
	$D + 4g' - 3\varpi + 3\varpi'$	...	...		...		...	−	0·49	...	
	1·0	(iii.) −0·01	+0·03	−	0·45		...		...	−	0·4
117	$4g' - 2\varpi + 2\varpi'$	(i.) (ii.) +0·15	−0·01		0·00	−	0·28	−	0·28	...	
					...		...		...	...	
	1·4	(iii.) +0·21	−0·02	−	0·13		...		...	−	0·3
60	$2g - 6g' + 4\varpi - 4\varpi'$	...	...		0·00	+	0·16	+	0·11	...	
	$2D - 4g' + 2\varpi - 2\varpi'$	...	...		...		...		...	...	
	1·1	(iii.) +0·06	+0·07	+	0·16		...		...	+	0·
79	$6g - 2g' + 4\varpi \quad 2\varpi'$	...	...		0·00	−	0·12	−	0·12	...	
	$6D - 4g' - 2\varpi + 4\varpi'$	...	...		...		...		...	...	
	1·3	(iii.) −0·01	0·00	−	0·12		...		...	−	0·1
34	$4g + 2\varpi$	(i.) −0·14	−0·10	−	4·10	−	4·00	−	4·01	...	
	$4D + 4g' - 2\varpi + 4\varpi'$	(ii.) −0·02	+0·06		...		...	−	4·01	...	
	1·0	(iii.) −0·01	+0·07	−	4·00		...		...	−	4·0
15	$2g + 2g' + 2\varpi'$	...	...	+	0·55	+	0·56	+	0·54	...	
	$2D + 4g' - 2\varpi + 4\varpi'$	...	...		...		...	+	0·54	...	
	1·0	(iii.) +0·03	−0·07	+	0·56		...		...	+	0·5
48	$g - 5g' + 2\varpi - 2\varpi'$	...	...		0·00	+	0·26	+	0·19	...	
	$D - 4g' + \varpi - \varpi'$	...	...		...		...		...	...	
	1·0	(iii.) −0·04	0·00	+	0·26		...		...	+	0·3

nt Tabular *minus* ed Coefficients of — sin periods 1– 48, 49– 89, 86–133	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	D₁. D₂.	Concluded Observed Coefficients
″	″	″	″	″	″
...	...	0·00	+ 0·27	+ 0·26	...
...	...	...	...	...	...
+0·05	+0·14	+ 0·27	...	...	+ 0·2
+0·06	−0·07	+ 0·40	+ 0·42	+ 0·42	...
−0·06	−0·07	...	...	+ 0·42	...
−0·03	0·00	+ 0·42	...	...	+ 0·4
−0·01	+0·04	+0·10	+ 0·11	+ 0·12	...
+0·09	+0·12	...	...	+ 0·11	...
+0·03	−0·10	+ 0·11	...	...	+ 0·
−0·07	+0·04	− 0·30	− 0·33	− 0·33	...
−0·08	0·00	...	...	− 0·33	...
+0·02	+0·05	− 0·33	...	...	− 0·

Reference No.	Argument. θ / sin θ	Apparent Tabular *minus* Observed Coefficients of sin / cos: (i.) periods 1– 48; (ii.) " 49– 89; (iii.) " 86–133	sin	cos	Tabular Coefficients. (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients. Hansen. Radau (R). Hill (H).	Theoretical Coefficients. D_1. D_2.	Concluded Observed Coefficients.
			″	″	″	″	″	″
112	2D − g + 2E − 2J	(i.)	+ 0·13	+ 0·46	− 0·89	...	...	...
		(ii.)	+ 0·55	+ 0·06	...	...	...	...
	1·0	(iii.)	+ 0·24	+ 0·03	− 0·89	− 0·88R	...	− 1·1
114	g − ☊	(i.)	+ 0·51	+ 0·09	...	..	...	...
		(ii.)	+ 0·57	+ 0·15	...	...	...	...
	1·0	(iii.)	+ 0·14	+ 0·19	− 0·52	− 0·52H	...	− 0·5
129	2E − 2M	(i.) (ii.)	− 0·30	+ 0·01	...	...	...	...
	1·0	(iii.)	− 0·06	0·00	+ 0·24	+ 0·23R	...	+ 0·3
130	E − J	(i.) (ii.)	+ 0·02	− 0·07	+ 0·70	...	...	...
	1·0	(iii.)	+ 0·01	− 0·13	+ 0·74	+ 0·65R	...	+ 0·7
124	2E − 2J	(i.) (ii.)	+ 0·09	− 0·01	− 0·20	...	...	...
	1·1	(iii.)	− 0·05	− 0·05	− 0·24	− 0·20R	...	− 0·2
133	E − 2J + 298°	(i.) (ii.)	− 0·24	− 0·06	...	...	...	...
	1·0	(iii.)	− 0·16	+ 0·04	...	+ 0·17R	...	+ 0·2
134	V − E	(i.) (ii.)	− 0·05	− 0·11	− 0·80	...	...	...
	1·0	(iii.)	− 0·34	− 0·02	− 1·10	− 0·86R	...	− 0·8
126	2V − 2E	(i.) (ii.)	+ 0·11	+ 0·02	+ 0·40	...	...	...
	1·0	(iii.)	+ 0·14	− 0·02	+ 0·43	+ 0·28R	...	+ 0·3
137	2V − 3E − 5°	(i.)	+ 0·05	+ 0·14	− 0·30 cos	...	...	...
		(ii.)	− 0·13	+ 0·10	...	...	...	...
	1·1	(iii.)	+ 0·22	+ 0·24	...	− 0·35R cos	...	− 0·3 cos
141	J + 9°	(i.)	+ 0·44	+ 0·50	...	...	...	...
		(ii.)	− 0·15	+ 0·19	...	...	...	...
	1·0	(iii.)	− 0·06	+ 0·14	...	− 0·14R cos	...	− 0·1 cos

ent Tabular *minus* ved Coefficients of: in periods 1– 48, 49– 89, 86–133 (sin)	cos	Tabular Coefficients (i.) Airy modified. (iii.) Hansen modified.	Theoretical Coefficients: Hansen. Radau (R). Hill (H).	D_1. D_2.	Concluded Observed Coefficient
″	″	″	″	″	″
+0·12	+0·33	...	...	...	...
+0·13	−0·18	...	...	...	...
−0·04	−0·02	− 0·05 sin	− 0·09R sin	...	− 0· si
		+ 0·09 cos	+ 0·06R cos	...	+ 0· co
+0·67	+0·50	...	...	...	...
+0·52	−0·50	...	...	...	...
−0·41	−0·12	− 0·32	− 0·42R	...	− 0·
−0·67	+0·87	...	...	...	...
−0·39	+0·62	...	...	...	...
−0·59	+0·73	...	+ 0·21R	...	+ 0·
+0·35	+0·97	− 6·60	...	...	...

87. Same remark as 96.

140. A term of nine years' period. Less accuracy may be expected in the observed coefficient. Delaunay's value is preferable to Hansen's.

85. Same remark as 96.

138. The first fifty years of the Airy period in many cases seem less accurate than the second fifty years. See term 141.

136. A similar remark to 140. Period, three years.

134.
13. } Similar remark as 96 ; characteristic e^2e'.

23. The principal elliptic inequality. This must be considered in connection with the terms 50 and 131. If we ignore these "allied" terms, the principal elliptic inequality would seem to be $22639''\cdot71$ from Airy and $22639''\cdot46$ from Hansen, a difference of $0''\cdot25$. But in term 50 Airy's tabular place exceeds Hansen's by $+0''\cdot34 \sin(g+D)$, which for a "g" analysis produces the apparent effect of $-0''\cdot17 \sin g$. This reduces the discordance to $0''\cdot08$. The full statement for the value of the principal elliptic inequality is this: Let $-8''\cdot54+a$ and $+18''\cdot60+\beta$ be the true coefficients of $\sin(g+D)$ and $\sin(g-D)$ respectively, corresponding to an approximate value $22639''\cdot5$ of the principal elliptic coefficient, then the principal elliptic coefficient according to the Airy period (1750–1851) is

$$22639''\cdot54+\tfrac{1}{2}a+\tfrac{1}{2}\beta,$$

and according to the Hansen period (1847—1901) it is

$$22639''\cdot46+\tfrac{1}{2}a+\tfrac{1}{2}\beta.$$

We know that the theoretical terms $g\pm\Omega$, $g\pm A'$ when A' denotes the argument of the 273 year *Venus* term ($A'-30^\circ\cdot2$ is Professor Newcomb's A defined numerically—lxiv. p. 421), combine with terms in $\sin\Omega \cos g$, $\sin A' \cos g$; while terms in $\sin g$ in both cases cancel out. There are undoubtedly other long-period terms which theory has not yet accounted for, and we may expect the same rule to hold good for these terms as well. Now if means for seventeen periods at a time be taken in the coefficients of $\sin g$ in vol. lxiv. p. 415 and Table IX. of this paper, and the coefficients of $\sin g$ thereby cleared of terms $g\pm\Omega$, $g\pm(\omega-\omega')$, $2D-g+3V-3E$, &c., it will be found that the values thus smoothed exhibit no trace of long-period inequalities, thus confirming the analogy with the theoretical long-period terms.

23 continued. The observed cosine term is a measure of the value of $\frac{1}{6}\Delta g$, where Δg is the error of the tabular mean anomaly. We may expect to find—and in fact I have found—traces of long inequalities in the values of $\cos g$. The observed coefficient $+1''\cdot14$ in 23 (ii.) shows how erroneous Airy's mean anomaly had become in the first half of the nineteenth century. Airy,

, omits all long-period inequalities. I must hold over, esent, the discussion of motion of the perigee.

he observed and theoretical evections are in close e. This disposes of a correction of Hansen's.

the tabular coefficients of terms 24 and 107 were so hat 24 (iii.) $+0{\cdot}70$ sin disappeared, I should expect to (iii.) $-0{\cdot}17$ sin approximately change sign, and in the observed coefficient for 1875 I have taken this tion into account.

7. The argument of 107 exceeds the argument of 24 $-4{\cdot}2557(p-44)$ at the middle of my pth period of The excess is therefore 163°, 334°, 162° for the middle riods denoted by (i.), (ii.), (iii.) respectively. Also in .) and (iii.) one argument gains 200° upon the other, eriod (ii.) 170°; putting $2\theta = 200°$ and 170°, we have

8 and 1·5. These data are sufficient to follow through

of altering the tabular coefficients to $+17''{\cdot}5$ and

we have to apply corrections

in $-0''{\cdot}7 \div 1{\cdot}8$ sin (arg. $+163°$) $= -0''{\cdot}1$ cos.

29. Again a suspicion of a small empirical term.

32. Again a suspicion of a small empirical term.

112, 114. The argument of 112 exceeds the argument of 114 by $320^\circ{\cdot}42 + 1^\circ{\cdot}4889\,(p-44)$ at the middle of my pth period of analysis. The excess is therefore 292°, 358°, 58° for the middle of the periods denoted by (i.), (ii.), (iii.) respectively. Also the relative motion is so slow that $\dfrac{\theta}{\sin\theta} = 1{\cdot}0$ approximately. If the tabular coefficients be altered to $-1''{\cdot}0$ and $-0''{\cdot}5$, then the following corrections must be applied :

To 112 (i.)

$$-0''{\cdot}1 \sin - 0''{\cdot}5 \sin(\text{arg.} - 292^\circ) = -0''{\cdot}3 \sin - 0''{\cdot}5 \cos.$$

To 112 (ii.)

$$-0''{\cdot}1 \sin - 0''{\cdot}5 \sin(\text{arg.} - 358^\circ) = -0''{\cdot}6 \sin.$$

To 112 (iii.)

$$-0''{\cdot}1 \sin.$$

To 114 (i.)

$$-0''{\cdot}5 \sin - 0''{\cdot}1 \sin(\text{arg.} + 292^\circ) = -0''{\cdot}5 \sin + 0''{\cdot}1 \cos.$$

To 114 (ii.)

$$-0''{\cdot}5 \sin - 0''{\cdot}1 \sin(\text{arg.} + 358^\circ) = -0''{\cdot}6 \sin.$$

To 114 (iii.)

$$-0''{\cdot}1 \sin(\text{arg.} + 58^\circ) = -0''{\cdot}1 \cos.$$

The application of these corrections to the apparent observed coefficients reduces them considerably. In particular the $+0''{\cdot}46 \cos$ in 112 (i.) is accounted for. The coefficient of $\sin(g - \Omega)$ is the same as that of $\sin(g + \Omega)$ with its sign changed.

142, 143, 144. The argument of 143 exceeds the argument of 142 by $233^\circ - 2^\circ{\cdot}414\,(p-44)$ at the middle of my pth period ; the argument of 143 exceeds the argument of 144 by $320^\circ + 1^\circ{\cdot}520\,(p-44)$; for the middle of periods denoted by (i.), (ii.), (iii.) the excess of 143 over 142 is 280°, 173°, 76° respectively ; the excess of 143 over 144 is 292°, 357°, 58° respectively ; and consequently the excess of 144 over 142 is 348°, 176°, 18° respectively. The values of $\dfrac{\theta}{\sin\theta}$ for periods (i.) and (iii.) are 1·2 for 142, 143 ; 1·1 for 143, 144 ; 1·7 for 142, 144 ; for period (ii.) the same quantities are 1·1, 1·0, 1·4. With these data the effect of altering the tabular coefficients to

$$-0''{\cdot}4, \; +0''{\cdot}2 \text{ and } -6''{\cdot}6 \sin - 0''{\cdot}7 \cos$$

may be followed through. We have to apply the corrections

To 142 (i.)

$$-0''{\cdot}4 \sin + (0''{\cdot}2 \div 1{\cdot}2) \sin(\text{arg.} + 280^\circ) - (0''{\cdot}7 \div 1{\cdot}7) \cos(\text{arg.} + 348^\circ)$$
$$= -0''{\cdot}5 \sin - 0''{\cdot}6 \cos.$$

(ii.)

$+(0''\cdot 2 \div 1\cdot 1)$ sin (arg. $+173^\circ$) $-(0''\cdot 7 \div 1\cdot 4)$ cos (arg. $+176^\circ$

$= -0''\cdot 6$ sin $+0''\cdot 4$ co

(iii.)

$-(0''\cdot 2 \div 1\cdot 2)$ sin (arg. $+\ 76^\circ$) $+(0''\cdot 7 \div 1\cdot 7)$ sin (arg. $+18$

$= +0''\cdot 3$ sin $+0''\cdot 3$ co

(i.)

$-(0''\cdot 4 \div 1\cdot 2)$ sin (arg. -280°) $-(0''\cdot 7 \div 1\cdot 1)$ cos (arg. -292°

$= +0''\cdot 7$ sin $-0''\cdot 6$ co

(ii.)

$-(0''\cdot 4 \div 1\cdot 1)$ sin (arg. -173°) $-(0''\cdot 7 \div 1\cdot 0)$ cos (arg. -357°

$= +0''\cdot 5$ sin $-0''\cdot 7$ co

(iii.)

$-(0''\cdot 1 \div 1\cdot 2)$ sin (arg. $-\ 76^\circ$) $+(0''\cdot 7 \div 1\cdot 1)$ sin (arg. -58°

$= +0''\cdot 5$ sin $-0''\cdot 5$ co

(i.)

$-(0''\cdot 4 \div 1\cdot 7)$ sin (arg. -348°) $+(0''\cdot 2 \div 1\cdot 1)$ sin (arg. $+292^\circ$

$= -0''\cdot 2$ sin $-0''\cdot 9$ co

(ii.)

$-(0''\cdot 4 \div 1\cdot 4)$ sin (arg. -176°) $+(0''\cdot 2 \div 1\cdot 0)$ sin (arg. $+357^\circ$

$= +0''\cdot 5$ sin $-0''\cdot 7$ co

(iii.)

lxiv. 572. Reference No. 16. *For* 0·38 *read* 0·68 (last column). Delete "term omitted by Airy."
" " 30. *For* 0·43 *read* 0·73 (last column). Delete "term omitted by Airy."
" 691. *For* argument 2ω *read* $180° + 2\omega$.

Mean Areas and Heliographic Latitudes of Sun-spots in the Year 1903, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lxiii. p. 464, and are deduced from the measurements of photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily area of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1903; and Table II. gives the same particulars for the entire year 1903 and the two preceding years for the sake of comparison. The areas are given in two forms: first, projected areas, that is to say, as seen and measured on the photographs, these being expressed as millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1903 the mean daily area of the whole spots (corrected for foreshortening), and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator; together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results for 1901 and 1902 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*, and for the years 1889 to 1902 on pp. 465 and 466 of vol. lxiii.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon of 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE I.

Date of ...mencement ...f each ...tation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
...902. d							
...c. 31·09	27	4	31	225	3	25	228
...903.							
...n. 27·42	27	21	127	535	17	102	611
...b. 23·77	24	18	100	396	14	85	455
...ar. 23·08	26	85	542	769	66	425	762
...r. 19·36	27	42	270	877	30	199	1053
...y 16·60	27	5	42	574	4	33	602
...ne 12·81	25	64	352	1018	42	249	1037
...ly 10·00	23	42	234	1261	30	175	1379
...g. 6·21	27	34	183	1371	21	122	1480
...pt. 2·46	26	17	95	769	17	93	846
29·73	27	188	1438	813	145	1188	959
...t. 27·02	27	224	1422	1192	171	1080	1401
...v. 23·33	27	138	854	1312	103	656	1535

TABLE II.

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
			°		°	°	°
1901	359	22	8·59	6·6	16·27	+2·82	10·37
1902	349	42	18·81	21	15·29	+7·48	17·64
1903	350	133	18·12	206	21·10	−5·75	19·93

The principal features of the record for 1903 are:

1. The increase in area;—the mean daily value for umbræ, whole spots, and faculæ being in each case between five and six times as great as in 1902, showing unmistakably that the revival of activity after minimum is in progress.

2. So far as umbræ and whole spots are concerned this increase was due chiefly to the remarkable activity shown in the last three months of the year, the mean daily area for the first nine months being less than one-half of that for the whole year.

3. The faculæ were less unevenly distributed through the year than the spots, the second half of the year being about twice as prolific as the first half.

4. Comparing the whole spots of the two hemispheres, the area for the northern has been to that of the southern as 39 to 61. This is contrary to the precedent of the last two cycles; for in 1880 and 1881, and again in 1890 and 1891, when the solar activity was increasing, a marked superiority was shown by the northern hemisphere.

5. Neither hemisphere has been absolutely undisturbed for a complete rotation at any time during the year.

6. The number of days without spots in 1903 was 56, as compared with 248 in 1902 and 289 in 1901. The last day without spots in 1903 was September 22.

7. The distribution of spots in latitude has been very characteristic of a new cycle when in full progress. The chief activity has been in the zone 15° to 25° in both hemispheres, whilst the belt of activity from 7° to 10°, recognised in 1902, has been almost quiescent.

8. As compared with the corresponding years of the two preceding cycles the mean daily spotted area appears rather low when taken into consideration with the mean distance from the equator of all spots. In 1880 the area was 416, and mean distance from equator 19°·85; and in 1891 the corresponding values were 569 and 20°·31.

9. The number of separate groups of spots was more than four times as great as in 1902, being 150 in all, of which 60 were in the northern hemisphere and 90 in the southern.

Royal Observatory, Greenwich:
1904 *December* 6.

vations of the Leonid Meteors of 1904 *November at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

nsiderable number of Leonids were observed on the of November 15 (civil reckoning). The following table e number counted by two observers during the watch :

G.C.T.	Number of Leonids.		G.C.T.	Number of Meteors.
h d h		d	h h	
22½—15 0	5	Nov. 15	3½—4	52
h h				
0—1	11		4 —4½	78
1—2	18		4½—5	65
2—3	22		5 —5½	58
3—3½	11		5½—6½	22

paths of the meteors were plotted till $3\frac{1}{2}^h$, but from the meteors were counted only, so that the numbers include a few not Leonids. Fog began to obscure the re $4\frac{1}{2}^h$, so that the time of maximum is not determined

falling at the horary rate of twenty-five for one observer, but my outlook was somewhat limited by obstructions.

After $15^h\ 45^m$ the fog increased and further observations could not be made.

The radiant of the Leonids was at $151° + 23°$. The meteors seemed apparently less bright than those forming the shower of 1903 November 15. The minor radiants of the period were unusually active, and the two most prominent of these were at $43° + 21°$ and $143° + 37°$.

I could not assure myself that the shower was increasing in intensity during my intermittent watch, but from several reports sent in by reliable observers it appears that the maximum occurred at about 16^h, or soon after that hour, when the rate of apparition reached one Leonid per minute. This would make the display somewhat richer than an ordinary Perseid shower and about one-fourth as strong as the Leonid return of 1903 November 15.

There were, however, a considerable number of brilliant Leonids recorded by various observers between 17^h and $17^h\ 17^m$, and I have received descriptions of twelve different meteors, equal to or exceeding first magnitude, which appeared during the short interval mentioned.

On November 15 at $14^h\ 40^m$ a magnificent meteor was seen at Charmouth and Torquay (where the observers estimated it as equal to the Full Moon and four times brighter than *Venus* respectively), and it appears to have been directed from a radiant in *Aries* and to have descended from eighty-three to thirty miles along a path of eighty-two miles over the north coast of France.

The fire ball lit up the sky vividly and must have presented a splendid effect over the English Channel.

Bishopston, Bristol:
1904 *December* 7.

A Comparison of the A. G. Catalogue (1900·0) *for Vienna (Ottakring) with the Radcliffe Third Catalogue* (1890·0). By F. A. Bellamy, M.A.

1. The publication of vol. ii. of the second or southern series of zone catalogues of the *Astronomische Gesellschaft* affords an opportunity of comparing this differential catalogue of stars with absolute places such as are given in the Radcliffe Third Catalogue (1890·0). In this Radcliffe Catalogue special attention was paid to stars south of the equator, with a view to establish a connection with the Cape (1880) Catalogue. The Vienna zone extending from $-6°$ to $-10°$ thus falls entirely

at region of the sky observed at the Radcliffe Observatory. mon to the two Catalogues are 967 in number, but, omit- amental stars, the number used is 923. The Radcliffe e, moreover, has a special interest for the writer, since a considerable share in the observations during his ent at that observatory; and he was thus led to make arison briefly described in the present paper.

e observations for the A. G. zone were commenced on uary 19, and finished on 1899 January 12; most of the ons were made during the years from 1893 to 1896. Some work was done after 1898. The instrument used was old meridian circle with an object-glass of 5·1 inches and 5 feet focus, and 120 magnifying power. The ob- s were made at the Kuffner Observatory at Ottakring .* The Radcliffe observations were made with the ircle, which is almost identical in size and power: its on may be found in the Radcliffe volumes.

ienna the transits were chronographically recorded and read by two microscopes 180° apart; the R.A.'s and a zone usually depend upon the observations of four to mental stars as given in Auwers's "Mittlere Oerter von nen nach den definitiven Fundamental-Katalog für die

up of A.	Right Ascension. R–V.	Diff. from Wt. Mean.	Correction to Radcliffe (from Auwers).	Diff. from Mean Corrected.	Declination. R–V.	Diff. from Wt. Mean.	Correction to Radcliffe (from Auwers).	Diff. from Mean Corrected.	Number of Stars.
h	s	s	s	s	″	″	″	″	
- 6	·000	+·024	–·008	+ ·016	+ ·56	– ·10	– ·06	– ·16	47
- 7	– ·022	+·002	–·007	– ·005	+ ·74	+ ·08	– ·06	+ ·02	48
- 8	– ·016	+·008	–·006	+ ·002	+ ·53	– ·13	– ·04	– ·17	40
- 9	– ·014	+·010	–·003	+ ·007	+ ·53	– ·13	– ·03	– ·16	43
-10	– ·038	–·014	·000	– ·014	+ ·45	– ·21	– ·05	– ·26	40
-11	– ·008	+·016	–·001	+ ·015	+ ·38	– ·28	– ·08	– ·36	29
-12	– ·028	–·004	–·008	– ·012	+ ·77	+ ·11	– ·09	+ ·02	41
-13	+ ·005	+·029	–·012	+ ·017	+ ·79	+ ·13	– ·10	+ ·03	36
-14	– ·016	+·008	–·012	– ·004	+ ·68	+ ·02	– ·11	– ·09	44
-15	+ ·011	+·035	–·011	+ ·024	+ ·89	+ ·23	– ·13	+ ·10	38
-16	– ·004	+·020	–·009	+ ·011	+1·04	+ ·38	– ·15	+ ·23	31
-17	– ·001	+·023	–·006	+ ·017	+0·92	+ ·26	– ·15	+ ·11	40
-18	– ·015	+·009	–·003	+ ·006	+ ·74	+ ·08	– ·13	– ·05	37
-19	– ·037	–·013	–·002	– ·015	+ ·40	– ·26	– ·11	– ·37	50
-20	– ·030	–·006	·000	– ·006	+ ·47	– ·19	– ·06	– ·25	47
-21	– ·039	–·015	+·002	– ·013	+ ·61	– ·05	– ·03	– ·08	40
-22	– ·035	–·011	+·006	– ·005	+ ·39	– ·27	·00	– ·27	41
-23	– ·039	–·015	+·011	– ·004	+ ·72	+ ·06	+ ·01	+ ·07	31
- 0	– ·035	–·011	+·016	+ ·005	+ ·75	+ ·09	·00	+ ·09	35
ighted Means	$-0^s{\cdot}024$				$+0''{\cdot}66$				923

4. In the table I have collected the mean differences for each hour of right ascension. With regard to the mean differences $-0^s{\cdot}024$ in R.A. and $+0''{\cdot}66$ in Dec., these are in great part due to the Radcliffe Catalogue. In *Monthly Notices*, vol. lv. p. 295, Mr. E. J. Stone deduced for the mean differences between Radcliffe (1890) and Greenwich (1880) for stars within the limits of $-5°$ and $-10°$ declination the values

$$\Delta\alpha(R-G) = -0^s{\cdot}017, \quad \text{and} \quad \Delta\delta = +0''{\cdot}91\ ;$$

and the systematic differences V–G would thus be

$$\Delta\alpha(V-G) = -0^s{\cdot}007, \quad \text{and} \quad \Delta\delta = -0''{\cdot}25.$$

But the differences in R.A. for the separate hours, which range from $-0^s{\cdot}068$ to $+^s{\cdot}011$, are greater than might be expected, considering the number of stars compared; the greatest negative quantity is $-0^s{\cdot}057$. If we subtract from the results for each hour the mean value of the whole, we get quantities under "difference from mean." The mean of these, without regard to

$^{s}\cdot015$; a glance at the residuals (third column) shows
siduals are systematically positive from 5^{h} to 18^{h}, while
8^{h} to 5^{h} are negative. The means of the two groups

$$\left.\begin{array}{ll} 5^{h}-18^{h} & \Delta\alpha = +0^{s}\cdot013 \\ 8-\ 5 & \Delta\alpha = -0\cdot015 \end{array}\right\} \text{ Difference, } 0^{s}\cdot028.$$

there are systematic differences in declination, but
t so prominent.
e the Vienna observations are based on Auwers's
se differences should be mainly due to the Radcliffe
The corrections required by Radcliffe to reduce to
ystem have been recently published * and are repro-
lumns 4 and 8 in the table. Inspection shows that if
nces R−V are entirely due to Radcliffe, Auwers's
should be approximately doubled. Thus the mean
given by Auwers for

$$\left.\begin{array}{ll} 5^{h}-18^{h} \text{ are} & \Delta\alpha = -0^{s}\cdot007 \\ 8-\ 5\ \ ,, & \Delta\alpha = +0\cdot005 \end{array}\right\} \text{ Difference, } 0^{s}\cdot012.$$

N.

DETACHED NEBULA IN CYGNUS

7. In the introduction to the Greenwich Second Ten-year Catalogue for 1890 a comparison is given for ten A. G. Catalogues. In a similar manner I have determined the mean differences $\Delta\alpha$ and $\Delta\delta$ from the 138 stars in Vienna and Greenwich Catalogues and for the thirty-six fundamental stars (Auwers). Proper motions have been applied. The following are the results:

	$\Delta\alpha$.	$\Delta\delta$.		$\Delta\alpha$.	$\Delta\delta$.	
$-6°$ to $-10°$	$-0^s{\cdot}01$	$-0''{\cdot}2$	138 stars;	$-0^s{\cdot}014$	$-0''{\cdot}36$	36 stars.

University Observatory, Oxford.

Detached Nebula in Cygnus. By W. S. Franks.

I was much interested in Dr. Max Wolf's paper on the remarkable nebula in *Cygnus* (*Monthly Notices*, vol. lxiv. p. 838), and thought it worth while to try it with the 20-inch reflector of this observatory. The accompanying photograph was obtained on 1904 November 12, with ninety minutes' exposure, between $21^h\ 36^m$ and $23^h\ 6^m$ local sidereal time; sky clear, but partial moonlight (Moon five days old). Another photograph was obtained simultaneously with the 5-inch camera, but, as it corroborates Max Wolf's in every respect, it is not necessary to reproduce it also. The scale adopted is $1^{mm} = 30''$ of arc; the extent of field shown is $1°\ 22'$ from *p* to *f* and $57'$ from *n* to *s*, the centre of plate being roughly in R.A. $21^h\ 49^m{\cdot}6$, Decl. $+46°\ 48'$ (1900). [The scale of Max Wolf's picture does not quite conform to the description, being only one-third instead of one-half of the present one; 1^{mm} on that is therefore equal to about $90''$, not $60''$.] Owing to the superior defining power of the reflector the detail is here more clearly shown than on the former plate, though the exposure was only ninety minutes as against four hours. Although it bears a family likeness to the "trifid" nebula in *Sagittarius* it is more complicated in structure; and, situated as it is in such a remarkably void region, it becomes a very interesting object. I have often noticed the curious thinning out of stars in the immediate vicinity of nebulæ, and undoubtedly there must be some physical cause to account for the fact, of which Sir W. Herschel was well aware. Is it possible that some of these objects are surrounded by *dark* and relatively cool nebulous matter, which, viewed in its greatest darkness round the edge, is sufficient to absorb and obliterate small stars behind it? We have no ground for assuming that the nebulæ generally are more distant than the stars; indeed, from their vast apparent size they may be much nearer. Considering, too, how few of the stars show any sensible parallax it may be that some of the nebulæ, when they are seriously attacked,

positive results. The long barren channel preceding
hed nebula (only part of which is visible on the scale
ate) is a very curious feature, and offers an inviting
peculation.

d Observatory, Crowborough Beacon.

Dark Nebulosities. By W. S. Franks.

time to time it has been hinted in a vague manner
des the ordinary self-luminous nebulosity, there exist
ertain forms of *non-luminous* nebulous matter, but, so
now, nothing definite has been advanced to account for
enomenon. However, that it does exist there can be
t after examining the evidence; I propose, therefore,
n certain objects which exhibit this curious appearance.
e course of a considerable experience in nebular photo-
have met with not a few of such, but have merely
ur of them as being good typical examples. As will

Fig. 1.

H V 19 Andromedæ.

Fig. 2.

H V 24 Comæ.

Fig. 3.

H I 43 Virginis.

Fig. 4.

H V 8 Leonis.

EXAMPLES OF DARK NEBULOSITIES.
Photographed by W. S. Franks.

On the Decline of the Visual Magnitude of Variable 159.1904 *Pegasi as observed at the Radcliffe Observatory, Oxford.* By Walter Wickham.

The *Zirkular Nr.* 68 *der Zentralstelle*, announcing the discovery by Mr. A. Stanley Williams of an apparently new star preceding B.D. 29°·4655, was received at Oxford on October 8, and the same evening the star was found in the place indicated, using the Barclay 10-inch equatorial.

The following four B.D. stars are conveniently situated for comparison, but are so nearly of an equal magnitude that it has not been easy to formulate a descending scale from them. The magnitudes here set down are those of (1) the original B.D., (2) the Cambridge (England) zone of the A.G.C., (3) my own readjustment of the values after careful comparisons on October 8, 11, 13, 18.

	B.D.	Camb. A.G.C.	Radc. 1904.
B.D. + 29·4659	8·8	9·0	9·11
·4652	8·9	8·9	8·91
·4653	9·2	9·1	8·79
·4655	9·1	9·1	9·01

The whole of the field was surveyed and provisional magnitudes assigned to about twenty of the fainter stars, extending the Argelander scale in descending steps by extrapolation. The results for the Stanley Williams star were:

	Oct. 8.	Oct. 11.	Oct. 13.	Oct. 18.	
	9·48	9·53	9·48	9·41	
from	(8)	(10)	(11)	(22)	comparison stars.

The close agreement of these values showed that there was very little, if any, change in magnitude. This conclusion was confirmed in *Ast. Nach.* 3971, 174–6 by Professor Pickering's telegram of October 7, "Williams star, long period variable, considered by spectrum," and by the notification of October 8 from Herr P. Gotz, Astrophysical Observatory, at Königstuhl, that on August 6–8 the star was nearly of the same magnitude as B.D. + 29°4653 (9·2 mag.). In *Ast. Nach.* 3973, 207–8, there appeared a note from Professor E. C. Pickering, "The Harvard photographs show that this object has existed for several years and is variable." Professor Max Wolf has published a chart of the region of the variable in *Ast. Nach.* 3977, 267–8, but does not mention the brightness, either visual or photographic, of the star on October 9, when the photograph was taken from which is reproduced the sketch he publishes.

The whole staff of this Observatory being engaged in other work of a routine character, and the clear nights so rare, no further attention could be given to this star until December 3,

found that it had decreased in brightness by a whole le. No opportunity for observation has since been the determinations are as follows:

Dec. 3.	Dec. 5.	Dec. 7.	Dec. 8 (sky becoming foggy).	
10·50	10·44	10·56	10·55	
(12)	(15)	(17)	(6)	comparison stars,

determination of their magnitudes.

eviously intimated the scale on which these estimations n made will probably require revision when standard ric values of the brightness of the comparison stars n published elsewhere; but it seemed advisable, in view arge change of brightness, to enlist the attention of who can follow the star with effective instruments continue to decrease to the point of visual extinction.

colour has been red throughout, increasing as the star ed, as was the case in the early changes of *Nova Persei.* phs taken with the 24-inch refractor of this Observatory er 8 and December 5 show the change of photographic y markedly.

I have used the Harvard photometric magnitudes of the stars, and have given the spectrum as observed at Harvard, A being the first or Sirian type, F intermediate between first and second types, G second or solar type, and K intermediate between second and third types

If M be the mass of a binary system, and p the parallax,

$$M = \frac{a^3}{p^3 P^2}.$$

Putting $M = 1$, we have

$$p = \frac{a}{P^{\frac{2}{3}}},$$

which is the "hypothetical parallax" on the assumption that the mass of the system is equal to the mass of the Sun. From this it follows that the smaller the parallax the larger the mass, and the greater the parallax the smaller the mass.

Binary Stars.

Star.	R.A. 1900·0.	Dec. 1900·0.	Mag.	P Years.	a.	Relative Brightness.	$h.p.$	Spectrum.	Computer of Orbit.
	h m	° ′			″		″		
Σ 3062	0 1	+57 53	6·10	104·6	1·37	0·89	0·06	F	See
η Cassiopeiæ	0 43	+57 17	3·64	500	11·4	1·36	0·18	F8G	Comstock
γ² Andromedæ	1 57·8	+41 51	5·00	55·0	0·34	16·37	0·024	A	Hussey
Σ 228	2 7·6	+47 2	6·03	88·7	0·98	1·49	0·05	F	Gore
40(o²) Eridani	4 10·7	− 7 49	9	180·0	4·79	0·01	0·15	...	Doolittle
55 Tauri	4 14·2	+16 18	6·86	200	0·85	2·73	0·025	E	Hussey
OΣ 82	4 17·1	+14 51	6·54	97·9	0·94	1·06	0·04	H	Hussey
β 883	4 44·6	+10 52	6·5	15·8	0·24	1·62	0·04	...	Lewis
Sirius	6 40·7	−16 35	−1·58	51·1	7·77	12·61	0·56	A	Zweirs
Castor	7 28·2	+32 6	1·58	346·8	5·75	16·08	0·116	A	Doberck
Procyon	7 34·1	+ 5 29	0·48	40·0	5·84	2·41	0·50	F5G	See
9 Argûs	7 47·1	−13 38	5·30	23·3	0·61	18·04	0·074	E	Burnham
ζ Cancri	8 6·5	+17 57	4·71	60·0	0·86	3·90	0·056	F	See
Σ 3121	9 12·0	+29 0	7·26	34·0	0·67	0·287	0·06	E	See
ω Leonis	9 23·1	+ 9 30	5·55	116·2	0·88	4·11	0·037	E	See
φ Ursæ Maj.	9 45·4	+54 32	4·54	99·7	0·32	64·62	0·015	A	Doberck
ξ Ursæ Maj.	11 12·9	+32 6	3·86	60·0	2·50	1	0·163	G	See
OΣ 234	11 25·4	+41 51	6·99	77·0	0·34	4·08	0·02	E (?)	See
OΣ 235	11 26·7	+61 38	5·38	66·0	0·83	3·47	0·05	F	Hussey
γ Centauri	12 36·0	−48 25	2·38	88·0	1·02	39·08	0·05	A	See
γ Virginis	12 36·6	− 0 54	2·91	194·0	3·99	5·60	0·119	F	See
42 Comæ Ber.	13 5·1	+18 4	4·47	25·5	0·64	2·85	0·074	F	See
25 Can. Ven.	13 33	+36 48	4·92	184	1·13	8·26	0·035	A	See

R.A. 1900·0.	Dec. 1900·0.	Mag.	P Years.	*a*.	Relative Brightness.	*h.p.*	Spectrum.	Comp of Or
h m	° ′			″		″		
3 44·6	+29 29	7·26	199·2	2·55	0·22	0·07	...	Biesbr
4 32·8	−60 25	0·06	81·1	17·70	0·99	0·94	{G K5M}	See
4 41·7	+42 48	7·24	97·9	0·34	4·65	0·016	...	Biesbr
4 46	+19 31	4·64	148·4	5·00	0·41	0·17	G	Biesbr
5 19·1	+30 39	5·13	41·6	0·86	1·43	0·076	F	Comst
5 20·7	+37 41	6·67	219·4	1·26	1·63	0·034	...	See
5 32·5	+40 8	6·69	56·6	0·88	0·55	0·06	...	Celoria
5 38·5	+26 37	3·93	73·0	0·73	13·02	0·04	A	See
6 10·9	+34 7	5·43	370·0	3·82	1·15	0·074	E	See
6 37·5	+31 47	3·00	35·0	1·43	3·29	0·134	G	See
7 12·1	−34 53	5·94	34·5	2·13	0·098	0·20	...	Gore
7 25·2	− 0 58	5·26	46·0	1·14	0·93	0·09	F (?)	See
7 42·6	+27 47	9	45·0	1·39	0·02	0·108	...	See
7 57·6	− 8 11	4·88	230·0	1·25	9·38	0·033	F	See

Omitting *Sirius*, *a Centauri*, and *Procyon*, which seem to be exceptionally near stars, we have the following results for the "hypothetical parallax :"

Spectrum.	Mean *h.p.*	Spectrum.	Mean *h.p.*
A	0″·044	F8G	0″·133
E	0·057	G	0·156
F	0·070	K	0·229
F5G	0·075		

showing a regular increase in the "hypothetical parallax" from spectrum A to spectrum K.

Notes on the above List.

1. Σ 3062. Components about 6·4, 7·0; colours yellowish and bluish white.

2. η Cassiopeiæ. Components 4 and 7; colours yellowish and purple. O. Struve found a parallax of 0″·154, and a parallax of 0″·3743 was found by Schweizer-Socoloff. With Struve's parallax mass of system = 1·6222 × Sun's mass.

3. γ^2 Andromedæ (B.C.) Components 5, 5·7; bluish. Orbit very eccentric and inclination high.

5. 40 (o^2) Eridani (B.C.) = Σ 518. Components 9, 10·8; yellow, orange. Gill found a parallax of 0″·166, Hall 0″·223. With Gill's parallax mass of system = 0·6963 × Sun's mass.

7. OΣ 82. Photographic magnitude 6·54. Components 7, 9.

9. Sirius. Components −1·58 and 10; white, yellow. Hussey says Zweir's orbit is "the most reliable that has yet appeared." From this orbit and Gill's parallax of 0″·37 we have mass of system = 3·5465 × Sun's mass. According to Auwers the ratio of the masses is 1 : 2·119. This gives for the masses 2·4094 and 1·1371 in terms of the Sun's mass. The companion being faint in proportion to its mass the relative brightness is evidently very small, and therefore the "relative brightness" of Sirius itself is probably considerably higher than that given in the table.

10. Castor. Components 1·99, 2·85; greenish. The brighter component is a spectroscopic binary with a relatively dark companion. Period 2·98 days. A parallax of 0″·198 was found by Johnson. This would make the mass of the system = 0·2042 × Sun's mass.

11. Procyon. Companion about 13 mag.; purple. Elkin found a parallax of 0″·266, and afterwards 0″·325. The first parallax would give a mass of 6·6, and the second a mass of 3·627 times the Sun's mass. Procyon has a proper motion of 1″·245 in the direction of position angle 214°·6.

12. 9 Argûs. Components 5·7, 6·3; yellow. Burnham says that his orbit represents recent measures satisfactorily. According to Auwers the star has a proper motion of 0″·351 in the direction of position angle 195°·4.

13. ζ Cancri (AB). Components 5·5, 6·2; yellow.

14. Σ 3121. Components 7·2, 7·5; white, yellowish.

15. ω Leonis = Σ 1356. Components 6, 7; yellow.

16. φ Ursæ Majoris. Components 5·5, 5·5; yellowish. The "relative brightness" is unusually high and the "hypothetical parallax" very small. With any larger parallax the mass of the system would be less than the Sun's mass.

17. ξ Ursæ Majoris. Components 4·41, 4·87; Harvard. This is the standard star used in the calculations of "relative brightness." A number of orbits have been computed, but in all the periods lie between fifty-eight and sixty-three years, and in most of them between sixty and sixty-two years. See says

of ξ Ursæ Majoris is practically all that can be desired in the present
ouble star measurement," and he thinks that the parallax may be
vely large. With the computed hypothetical parallax I find that the
l be reduced to 4·00 magnitude, or about the same brightness as the
ording to Lewis the mass of the companion is greater than the mass
imary star in the ratio of 3 : 2 (*The Observatory*, 1904 November).
ajoris is also a spectroscopic binary, so that the system is really a

Σ 234. Components 7, 7·8; yellowish.
Σ 235. Components 6, 7·8; yellowish. The orbit is somewhat doubtful
to Hussey.
Centauri. Components 3, 3; yellowish.
Virginis. Components 3·65, 3·68, Harvard. Orbit good. Belopolsky
arallax of 0″·051 and a mass equal to fifteen times the Sun's mass.
Comæ Berenicis. Components 5·2, 5·2; orange. Orbit satisfactory.
Canum Venaticorum. Components 5, 8·5; white, blue.
1785. Components 7·3, 7·5; pale yellow, bluish. Orbit published

Centauri. Components 0·36 (spectrum G) and 1·61 (spectrum
Harvard. Both orange yellow. A parallax of 0″·75 was found by
0″·76 by Wright and Palmer from spectroscopic measures of relative
With Gill's parallax mass of system = 2·00 × Sun's mass. Masses
nents nearly equal. If we take the density of companion as 2·0
4), I find luminosity of primary = 2·52 × luminosity of companion or
rightness = 0·39.
Σ 285. Components 7·5, 7·6; yellowish, whitish. Spectrum not in the

45. δ Equulei. Components 5, 5·5; yellow. Hussey finds mass of system = 1·89 × Sun's mass and parallax = 0″·071, from spectroscopic measures.

46. τ Cygni. Components 4, 10. Burnham thinks the orbit doubtful and suggests that the companion is double, and on this hypothesis he has based his orbit.

47. κ Pegasi. Components 4·5, 5·0; yellowish. The brighter component is a spectroscopic binary. From the spectroscopic measures of 24·8 miles a second and period of six days I find a probable mass of the system = 0·48 × Sun's mass, and a parallax of 0″·106. This would reduce the Sun to a star of about 4·87 magnitude.

48. 85 Pegasi. Components 6, 10; yellowish, bluish. Brunnow found a parallax of 0″·054. This, with See's orbit, gives the mass of the system = 7·77 × Sun's mass. From measures of the binary and a distant 9th magnitude star Comstock, using a parallax of 0″·04, finds a mass of 11·3, the mass of A being 4·3 and that of B = 7·0 in terms of the Sun's mass = 1. With reference to this "remarkable" result he says, "A star A whose spectrum is of the second type (E in the Draper Catalogue) emits more than 100 times the light of its companion B, although B is presumably of equal age with A, and possesses 60 per cent. more mass than the latter star" (*Astrophysical Journal*, vol. xvii. p. 223). The companion is possibly gaseous. 85 Pegasi has a large proper motion of about 1″·3 per annum in the direction of position angle 140°.

On the Relative Efficiency of Different Methods of Determining Longitudes on Jupiter. By A. Stanley Williams.

I have read Professor G. W. Hough's paper "On the Determination of Longitude on the Planet *Jupiter*" in the Supplementary Number of the *Monthly Notices* very carefully, but fail to see any reasons for modifying the conclusions come to in my previous communication on this subject, in the March number. It seems to me that much of what he says has no direct bearing upon the subject and only tends to obscure the real questions at issue, and there are, moreover, several misstatements and misconceptions on his part. The position is simply this: In my previous communication I discussed in a particular manner not merely a few selected observations of a limited number of spots, but a very large amount of work done by Professor Hough with the micrometer upon numerous spots, and in addition I included his fine series of observations of the red spot, made when that remarkable object was at its maximum plainness. The first was to show the degree of accuracy attained by the micrometric method in general work, and the last what could be accomplished under the most favourable circumstances. I also discussed *in exactly the same manner* a correspondingly large number of observations of many different spots by the method of transits, made by various observers, and I came to the conclusion, as the result of this *exactly similar comparison*, that the apparent errors of the observations are about the same with either method, or, in other words, that the two methods

ctically results of equal accuracy.* Now in order to
t this conclusion is erroneous it is necessary to show
t the mode of discussing or comparing the observations
l by me unduly favours the method of transits at the
of the micrometric method or else that the selection of
ons by the former method made by me is not a fair one,
e does not really represent the average work of careful
. And I submit that Professor Hough has not done
these things, or in fact even weakened in the slightest
e force of my conclusions.

irstly, with regard to the mode of discussing the observa-
matters little if at all for our purpose whether we take
obable error," or the "mean error," or the "mean
" or any other form of expressing the apparent "error,"
icating the accordance of the observations. The only
real importance is that *exactly the same kind of "error"*
used in discussing the observations made by both the
ods in order to properly and fairly compare the results
, and this is what I have done in my previous paper.†
l for the purpose in view not the "average residual"
"mean error" of an observation as defined in § 26 of
ork on *The Theory of Errors of Observations*; and
ult included in my paper is expressed in this form of

The same thing will apply to Professor Hough's "corrected" value for Professor Barnard's observations of the red spot, 1901, on p. 824 of the *Monthly Notices*, and to other differences instanced by him on that page, though I do not understand how some of his figures have been arrived at.* The mean error of Jedrzejewicz's observations is certainly $\pm 0^{m}\cdot 5$. It is doubtful if the use of a micrometer in the manner employed by this observer is of any advantage. In every case, with the single exception referred to above, the values given in my lists are correct, and Professor Hough is not justified in altering them.

Secondly, as regards the selection of the observations by the method of transits, Professor Hough affirms that "the table of so-called data consists almost entirely of the comparison of five or six observations *inter se*, selecting such as show a small mean residual." The first part of his statement, so far as it is correct, applies also to the results of his own micrometric observations. The last part of it is, however, quite incorrect. What I actually did was to search through all the likely periodical literature readily accessible to me for a good many years back, and I included in my lists and published *every instance* come across in my search, except as mentioned below, *entirely regardless* whether the residuals were small or large. The only cases rejected were, as mentioned in my paper, a few in which there were only three. or (in one case only) four observations of a spot, and where consequently the mean error could not be ascertained with any exactness. I submit, therefore, that the data published in the lists in my paper represent *the fair average work* of careful observers in general by the method of transits, particularly if the adverse circumstances referred to in § 12 of the above-mentioned paper are borne in mind. The observations were certainly not selected on account of the smallness of the residuals. Is Professor Hough quite correct, though, in saying that "Barnard, without any investigation, *thought* some of his observations would have a mean error $\pm 0^{m}\cdot 7$"? In *Pub. A. S. P.*, vol. i. p. 91, Professor Barnard makes the definite statement that from twenty-three transits of the red spot "I get for the transit of the middle from the mean of the nine observations the error of the transit $= \pm 0^{m}\cdot 7$." I did not, however, as stated by Professor Hough, incorporate Barnard's data in my table, but assumed a larger mean error ($\pm 1^{m}\cdot 0$). With this single

* For instance, Professor Hough states (p. 824) that my result for the red spot 1900 "carries a mean residual $\pm 2^{m}\cdot 8$, *not* $\pm 0^{m}\cdot 8$." But the actual residuals given by my observations are, $-0^{m}\cdot 2$, $-0^{m}\cdot 1$, $+1^{m}\cdot 2$, and $-0^{m}\cdot 9$ (*A. N.* 3675). The mean error is $\pm 0^{m}\cdot 8$, as correctly stated in my paper, the mean residual being $\pm 0''\cdot 6$. Professor Hough's figures for the mean error differ so frequently from mine that some additional data contained in his lists on pp. 828 and 829 of the *Monthly Notices* cannot possibly be accepted as comparable without examination. As this would entail the calculation of the rotation periods of the spots and the computation of the residuals shown by the observations this work must be deferred.

ı the values given in my lists are correct and cannot ioned.

ubtless would not be difficult to select from the large of published observations by the method of transits, by good, bad, and indifferent, and sometimes with quite escopes, instances of large or apparently variable errors, no doubt will account for some of the discordances that n referred to. Even in the case of the comparatively mber of published micrometer observations it is not to pick out such instances. For example, the mean previously defined, of Professor Hough's twenty-five ions of the red spot in 1894–5 * is as large as $\pm 3^{m}\cdot 5$, e are residuals as great as $-10^{m}\cdot 0$ and $+11^{m}\cdot 6$. In rds, there is an extreme difference of $21^{m}\cdot 6$ in the time it of the red spot as deduced from the micrometer ! It should be mentioned here that I purposely this result from the list on p. 431 of the *Monthly Notices,* t seemed to me that it would not be fair to the micro-ethod to include it, since Professor Hough remarks that vations were "comparatively rough, for the reason that was often too indistinct to see any definite outline." other hand I did include the comparatively large mean

If we divide the data in question into two classes, treating all spots with less than ten observations as having a small number of observations, and those with ten or more observations as having a large number, we shall get the following figures:

Average Mean Error. Method of Transits.

	Small No. of Obs.	No. of Cases.	Large No. of Obs.	No. of Cases.
	m		m	
Red spot	± 1·8	3	± 1·7	13
Other spots	± 1·9	12	± 2·0	6

Average Mean Error. Micrometric Method.

	Small No. of Obs.	No. of Cases.	Large No. of Obs.	No. of Cases.
	m		m	
Other spots	± 1·8	10	± 2·5	5

In forming the first result I have omitted the first item in the list on p. 433 of the *Monthly Notices*, as this has been questioned. It will be seen that the spots with only a small number of observations give very nearly the same average mean error as the spots with a large number of observations so far as the method of transits is concerned. But—and this is somewhat curious—in the case of Professor Hough's micrometric measures the average mean error from spots with only a few observations is decidedly smaller than that shown by the spots with a large number of observations. In other words, the effect of including the spots with a small number of observations has been to *reduce* the magnitude of the average mean error in the case of the micrometric method, so that Professor Hough in objecting to the inclusion of such instances has actually been unwittingly damaging his own case! So far as the method of transits is concerned it makes practically no difference if the spots with only a small number of observations are omitted. It is interesting to contrast the position taken up here by Professor Hough with respect to fictitiously small errors deduced from a few observations with his treatment of the small residuals shown by his few *Saturn* observations in the *Monthly Notices* for January and April of this year. Yet the probabilities are vastly greater that the small residuals of the latter are "fictitious" than they are in any of the cases included in my lists, even if it were certain that all his observations related to the same spot.

Surely Professor Hough is not speaking seriously when he says (p. 825) that "if Schmidt's corrections were valid . . . the corrected observations can no longer be regarded as eye-estimates"? I cannot believe that this is really what he meant to say. No doubt these corrections are of an empirical nature, but they certainly do diminish the magnitude of the

considerably, whilst the observations are numerous
give grounds for accepting them. I quite fail, how-
ee why a constant error varying with the position of
should necessarily "show the untrustworthy nature
timates." Surely not if we can ascertain its value at
Can Professor Hough point out any instance of a
rrection varying with the hour angle and affecting the
ns of any other observer? It would seem that if the
on he suggests for the origin of this error is correct,
ffects, so far at any rate as regards its variable part,
eliminated by always observing with the eyes parallel
elts. In this connection it seems proper to inquire
Professor Hough always makes his measures with his
he same invariable position with respect to the belts?
the experience of those engaged in astrographic work
m to show that appreciable errors might creep in. It
sirable that Schmidt's observations should be redis-
om the point of view of a rotation period varying
with the time, in the manner adopted by Professor
reducing his own observations. Such a rediscussion
terially reduce the apparent errors of the uncorrected

telescope used.* These observations of mine are, therefore, no more adapted to indicate the accuracy attainable by the method of transits than are Professor Hough's own observations of 1894–5 so suited with regard to the micrometric method. Next, in order to show the unfairness of discussing the observations of one observer mixed up with those of others, I give below my own observations apart from those of Mr. Denning. The weights on the scale, 1–5, have been added from p. 96 of my *Zenographical Fragments*, but otherwise the figures have been taken from Professor Hough's paper, excepting that the residuals O – E have been determined afresh.

1886.	Williams Longitude. m	Wt.	O – E. m
Dec. 20	– 11·0	1	+ 2·0
1887. Jan. 1	– 6·0	1	+ 7·0
Feb. 26	– 4·8	1	+ 8·2
Mar. 20	– 3·9	1	+ 9·1
„ 27	– 6·9	1	+ 6·1
„ 29	– 15·8	1	– 2·8
Apr. 3	– 9·9	2	+ 3·1
„ 10	– 21·8	1	– 8·8
„ 17	– 12·7	2	+ 0·3
„ 20	– 13·8	3	– 0·8
„ 24	– 15·2	2	– 2·2
„ 27	– 14·9	1	– 1·9
„ 29	– 17·9	1	– 4·9
May 2	– 15·6	1	– 2·6
„ 14	– 15·1	1	– 2·1
June 19	– 21·0	1	– 8·0
	Mean error =		± 4·4

1886.	Denning Longitude. m	O – E. m
Nov. 23	– 2·5	+ 6·9
Dec. 17	– 4·9	+ 4·5
1887. May 7	– 15·5	– 6·1
„ 9†	– 15·5	– 6·1
„ 10	– 13·8	– 4·4
„ 26	– 14·8	– 5·4
June 10	– 11·3	– 1·9
„ 22	– 6·1	+ 3·3
July 16	– 5·8	+ 3·6
Aug. 6	– 4·2	+ 5·2
	Mean error =	± 4·7

The mean error of an observation is here $\pm 4^{m}\cdot 4$, not $\pm 4^{m}\cdot 7$, as given by Professor Hough on p. 827 of the *Monthly Notices*, or $\pm 4^{m}\cdot 9$ on p. 829, but it is evident that the observations are not well satisfied by Marth's ephemeris ; there is a preponderance of plus residuals in the first half of the series and of minus ones

* In *Popular Astronomy* for 1903, p. 69, Prof. Hough states that "my measures, when the spot was very indistinct, have been referred to the centre of the bay" of the S. equatorial belt. In light of this statement it seems probable that the Dearborn observations of 1887, published on p. 827 of the *Monthly Notices*, do not relate to the red spot at all, but to the deep bay or hollow in the S. equatorial belt—a different feature altogether.

† This observation is attributed to W. D. in the table in Professor Hough's paper, but it was actually made by D. W. only observed the following end of the spot.

t half. A slight shortening of the rotation period ding to the ephemeris would considerably reduce the of these residuals, poor though the observations y are.* It will be seen that *no less than* 12 of the ns have the lowest weight 1, and also that the four ns with higher weights give much smaller residuals, error in fact of these four observations being only ghtly less than that given by the Dearborn observa-

enning's observations are given separately on the right above table. The mean error is here $\pm 4^{m}{\cdot}7$, but with these observations it should be remarked that the first have been made under most disadvantageous conditions, planet was quite close to the Sun and its altitude very robably were the last two or three observations.† Now simple and it seems to me good reason why these ns made under such unfavourable circumstances should residuals, and this reason is the faintness of the end of the red spot in 1887. This is referred to on my *Zenographical Fragments*, and it was there pointed owing to this peculiarity, there would be a tendency for ent centre of the spot to shift towards the following

changes of period, neither do Mr. Denning's if the above explanation of the origin of the plus residuals in his early and late observations be accepted.* In any case a few discordant observations of a very faint spot made under what must have been very unfavourable conditions could not be held to prove them. Even when my book was written I was very doubtful as to the reality of the changes in question, and used the qualifying words "according to the observations" in referring to them. Professor Hough's remark that "here we have apparently a well-established fluctuation in the rotation period of 5·2 seconds which did not exist" therefore loses all sense. With my present knowledge of the different manner in which different observers may regard the same planetary marking I should not dream of coming to any such conclusion from the published observations, or from a comparison of the observations of two different observers, even if they related to a conspicuous spot. It is apparently from cases like the foregoing, based on the comparison of 16 observations of a very faint spot, 12 of which are clearly stated to be bad ones, by one observer, mixed up with 10 observations, some of which must have been of a very rough character, by another observer, and without making any adequate investigation himself into the circumstances, that Professor Hough largely bases his condemnation of the method of transits! His observations of the red spot in 1894–5 have already been alluded to, and I give them below for comparison with the above. They have been taken from his paper in the *Astr. Nach.* 3354, but the residuals O—E have been added by the writer.

	Hough Longitude.	O—E.		Hough Longitude.	O—E.
1894.	m	m	1895.	m	m
Sept. 26	+ 1·1	− 3·5	Feb. 2	+ 3·1	− 1·5
Oct. 10	− 5·4	− 10·0	„ 14	+ 6·1	+ 1·5
Dec. 3	+ 9·1	+ 4·5	„ 16	+ 5·6	+ 1·0
„ 8	+ 6·8	+ 2·2	„ 19	+ 1·7	− 2·9
„ 13	+ 11·2	+ 6·6	„ 21	+ 4·9	+ 0·3
„ 25	+ 16·2	+ 11·6	„ 23	+ 6·8	+ 2·2
„ 28	+ 4·3	− 0·3	„ 26	+ 8·9	+ 4·3
1895. Jan. 2	+ 2·2	− 2·4	Mar. 5	+ 1·8	− 2·8
„ 9	+ 8·4	+ 3·8	„ 10	+ 5·7	+ 1·1
„ 16	+ 1·8	− 2·8	„ 19	+ 9·4	+ 4·8
„ 23	+ 5·4	+ 0·8	Apr. 3	− 0·7	− 5·3
„ 26	− 2·6	− 7·2	„ 10	+ 3·9	− 0·9
„ 28	+ 0·5	− 4·1		Mean error =	± 3·5

* In answer to an inquiry respecting his observations of 1887 Mr. Denning writes that "my observations of the red spot in 1887 were very unsatisfactory, owing to the faintness of the object and to the bad definition

eady stated the mean error of an observation is here
vhilst there are residuals amounting to $-10^{m}\cdot0$ and
The grouping of the residuals is also interesting and
e in comparison with the foregoing observations of
oth at the beginning and end of the series are rather
us residuals; whilst the curious way in which plus or
iduals are repeatedly grouped together suggests that the
several times in the course of the observations suddenly
his habit of observing. If the first two observations
een made a different conclusion might have been come
ing the rotation period of the spot in 1894–5. I do
that my observations of 1887 can be said to compare
ably with these ones of Professor Hough, which latter
said to be "comparatively" rough. It is easy to see,
that if only the two observations at the commencement
wo at the end had been made, with a few of the inter-
ones, the result might have resembled Mr. Denning's
tty closely, with reversed signs.

we are able to compare contemporaneous series of
ons by several observers using the micrometric method,*
to me idle and useless to enter into the question of
equation, or of what Professor Hough calls "variable

drawings of the period will show, I venture to think, that differences of the kind must necessarily arise. Some observers, for instance, draw the red spot at this time neatly rounded off at the ends; others show the ends pointed; others with the ends not only pointed, but drawn out into fine lines; yet others with the ends dissimilar; and so on. Dr. O. Lohse once saw the spot with the following end rounded off, but with the preceding end pointed and unsymmetrically flattened, the point being, moreover, extended into a fine line. I doubt if any two observers would agree as to what constituted the middle of such an object, the appearance of which might vary largely with the conditions of the seeing and the size of the telescope used. Professor Hough has himself drawn the following half of the red spot much broader than the preceding half. How would he measure such an object? Would he measure a point midway between the two ends, or would he measure what appeared to be the centre of figure of the spot? Again, a very common form of spot on *Jupiter* takes the shape of a dark mass projecting obliquely from a dark belt into one of the bright zones. Such spots are frequently exceedingly dark and definite at the projecting part, and from thence fade off gradually. Probably again no two observers would agree as to what is the middle of such a spot, and whilst some would no doubt try to observe the middle, or the spot, as one mass, others, including the writer, would probably observe the more definite little projecting part, though this might be far removed from the centre of the mass. On a poor night this more definite projecting part might be obliterated, and then the last-mentioned observers would necessarily observe the spot as one mass, or its apparent middle. This is probably one and a very common way in which what Professor Hough calls "variable error" arises; but micrometer measures would assuredly be affected in the same manner. It is not difficult to see how differences amounting to 5 or even 10 minutes in the time of transit might occur in this manner; and, as every spot may be said to have its own peculiarities of appearance, personal equation or "variable error" originating in this manner might be expected to differ in the case of different spots, as is actually the case. From the Dearborn observations of the red spot of 1894–5 it would not be difficult to pick out two or three "variable errors." Another instance of the kind may be referred to as occurring in Professor Hough's famous early series of observations of the red spot. In 1881 he observed the red spot in a pretty uniform manner for a couple of months up to December 28, when a sudden change seems to have taken place in his habit of observing, and during 1882 January he systematically observed the transits, as deduced from his micrometer measures, nearly 4 minutes earlier. These, and other cases that could be adduced, show clearly that, even according to our present knowledge, Professor Hough must be wrong in assuming that the micrometric method is free from this "variable error."

[Return]ing again to these Dearborn observations of 1894–5 of [the red s]pot, it is possible that they may furnish the key to the [explanation of] some part, though only some part, of this "variable [error]. T]hey seem to indicate that perhaps observers may not [always ha]ve been careful to distinguish between the centre of [figure and] the centre of mass, or intensity, of the red spot, and [somet]imes have observed the one and sometimes—particularly [in bad see]ing—the other.

[Some] importance seems to be attached to the accordance of [measures m]ade on the same night before and after the central [passage of] a spot; but although this, if correct, would show that [the same] observer on the same night, and after the lapse of [an ho]ur or two, may measure a spot in the same manner, [it doe]s not prove in the least that another observer, with [another te]lescope and at another place, with different conditions [of seein]g, must measure the same spot in the same manner, [or even] the first observer on a different night and under [different c]onditions. It has no bearing upon this question at [all. Such] accordance would indicate that the disc of the planet [was correctl]y bisected, but would the measures show that the *spot* [was simila]rly bisected? But I do not think that Professor [Hough is j]ustified in making the statement as to the accordance

1882, p. 51)? Concerning this spot he remarks that "during 1881 the single spot, observed continuously for a period of 252 days, indicated *sudden deviations* in its apparent place . . . the comparison with the ephemeris shows a maximum displacement of sixteen minutes of time."* The italics are mine. As a matter of fact it is chiefly in the equatorial regions of *Jupiter* that "sudden deviations" of this kind occur, according to observations made by the method of transits, and it can only be because Professor Hough has not apparently observed a large number of these equatorial spots in a sufficiently continuous manner that he has not frequently come across similar deviations revealed by his micrometer measures. These deviations or wanderings, as I have termed them, are familiar to every systematic observer of the equatorial markings. They were first pointed out, I believe, by Herschel in 1780,† and their existence led this distinguished astronomer to abandon the planet *Jupiter* for *Mars*, so far as the chief purpose he had in view at the time was concerned—namely, the question of determining whether the *Earth's* diurnal motion is perfectly equable.

The reason for my venturing to question the correctness of Professor Hough's identification of four observations of an equatorial spot (*Monthly Notices*, p. 833) is that the accordant observations of four different observers show that there were several similar equatorial spots near the same place, and his four observations fit in with three separate spots. As to the number of observations required to insure correct identification, opinions will, no doubt, differ, but it does not seem as though four observations of an equatorial spot scattered over an interval of eighty days is sufficient. In this particular case two of them moreover are close together at the end, so that practically the identification is dependent upon three observations, separated by thirty-seven and forty-one days. A glance over the observations of the spot referred to in the preceding paragraph will satisfy any one, I should think, that the identification might well be incorrect under such circumstances when there are several similar spots close together.

With regard to *Saturn*, since the rotation of this planet and that of *Jupiter* is performed in nearly the same time, the reduction in scale due to the greater distance and smaller size of the

* I find that Mr. Denning had already called attention to this in the *Monthly Notices* for June last, p. 768.

† *Phil. Trans.*, 1781, p. 126. These deviations or wanderings occur in the case of the neatest and most definite markings, and they cannot possibly be confounded with any of the discordances of the nature of personal equation or variable error, for the following reasons: (1) They are attested by the accordant contemporaneous observations of several different observers. (2) They may cause differences in the time of transit of a spot so considerable as to amount to more than half an hour in a few days. (3) They may affect nearly simultaneously several adjacent spots, whilst other similar spots, in the same latitude but in a different longitude, at the same time remain unaffected.

ınet must affect the accuracy of the results obtained by
netric method. The reduction in scale actually amounts
e-half, and, since the Dearborn micrometrical measures
spots give an average mean error of $\pm 2^m$ in the
ime of transit of a spot, it follows that similar measures
n *Saturn* may be expected to have a mean error of
^{m}. This is, I should imagine, a minimum value, and it
nearly twice as large in the case of an individual spot.
ny reason why the method of transits should undergo a
eduction in accuracy than the micrometric method?
vations of Professor Barnard, quoted on p. 832 of the
Notices, show clearly what an indefinite and difficult
spot must have been, but would micrometer measures
object have given a more accurate result than a central
transit? I doubt it very much.
are several other matters considered in Professor
aper that ought to be gone into, but this communication
y reached to an undue length and their consideration
eferred. Some of them do not seem to require noticing.
rdly add that any conclusions come to in his paper, so
y imply any superiority on the part of the micrometric
re not warranted by the known facts.
confess that I have been surprised to find that the

observations used a micrometer with one wire bisecting the disc, presumably set so as to indicate the measured half-diameter of the planet, so that Barnard's *central meridian* can hardly have differed in the sense implied. Concerning the direct measures of the distance between the two spots Professor Barnard writes that "although the spots were usually very conspicuous, it was found that they were quite ill-defined and rather difficult when the wires were placed over them." * This statement seems to support the suggestion made above as to the possible prejudicial effect of a micrometer wire in altering the appearance of a spot. Without a micrometer these spots were almost ideal objects for observation.

Hove: 1904 *November* 29.

On the Eclipse of Agathocles. By Simon Newcomb.

In my "Researches on the Motion of the Moon," which appeared in 1878, I made a careful study of the accounts of supposed total eclipses of the Sun by ancient authors, with a view of determining whether any of them could be used either as tests of the lunar tables, or as auxiliaries in the determination of the slow changes in the lunar elements. The conditions required for this use were that some determinable eclipse should have been total at a known place. The conclusion which I reached was strongly in the negative. Not only did there appear to be no ancient eclipse which we could conclude was really total at a given place; but the accounts were generally so vague that no interest seemed to attach even to a comparison with the lunar tables, except for chronological or historical purposes.

I may add, in all frankness, that these adverse views have not been shared by those astronomers who, in the meantime, have made researches on the subject. Oppolzer and, after him, Ginzel had such confidence in the reality of these eclipses as to use them as the basis of corrections to the elements of the Moon's motion which are incompatible with gravitational theory. I have no intention to argue my view at present further than to say that I am not at all convinced it was in any point ill founded, so far as related to data available at the time. But since my paper was published a very important point has been brought to light showing an exception to the conclusions there reached. This arises in connection with the eclipse of Agathocles −309 August 14.

This eclipse has been so fully discussed by Airy and others that only a very brief statement of the circumstances connected

* *Monthly Notices*, vol. li. p. 549.

necessary. The eclipse was observed from the fleet of
es about 10 o'clock A.M. of the day after it put to sea
acuse. There is no doubt about the fleet having been
in the line of totality. Unfortunately it is uncertain,
orical evidence, whether Agathocles sailed to the north
south of Sicily. Consequently there are two possible
of his fleet, one to the south of the island, the other
north-east point. Moreover, the path of totality was
ad, the radius being about 50′, thus much widening the
uncertainty.

gives real importance to this eclipse is its identifica-
Celoria with one referred to by Cleomedes, during which
vas said to have been entirely eclipsed in the Hellespont,
e fifth of its diameter was still visible at Alexandria.
rds a very strong presumption that the path of totality
er the Hellespont. Yet the path does not reach the
it by the tables either of Oppolzer or Ginzel, the central
g a hundred miles or more to the south. What I have
is to make a computation of the path of totality from
s based on the corrected theory found in the researches
lluded to, using the tables in the astronomical papers of
ican Ephemeris, vol. i., as well as testing the result by a
l reduction of Hansen's results given in his "Darlegung."

any change on account of the observed discordance. Possibly this was not the best course in a case where so much suspicion may attach to a record. Mr. Nevill's conclusion was that my result should have been still further diminished by at least $1''$, and perhaps $1''\cdot5$. This view is now strengthened by the eclipse of Agathocles.

The important point is that this reduction will carry the observed acceleration down almost to the theoretical value, in which no allowance is made for tidal retardation. In other words, the conclusion to which the new evidence points is that the actual retardation of the Earth's rotation is almost evanescent. Although no numerical determination of the probable amount of retardation, as given by theory, has, so far as I know, ever been made, I think any estimate must make probable a value larger even than that corresponding to my former result. It therefore seems likely that a neutralisation of the effect of tidal friction is produced by some cause not yet fully investigated.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Professor H. H. TURNER, D.Sc., F.R.S., PRESIDENT, in the Chair.

Alexander John Samuel Adams, Post Office Telegraphs, London E.C.,, and 32 Casella Road, New Cross, S.E.;
Capt. Arthur ffolliott Garrett, R.E., Craigbeg, Kingussie, Scotland;
P. Groves-Showell, L.C.C. School for Marine Engineering, High Street, Poplar, E.;
George Bruce Halsted, A.M., Ph.D., Kenyon College, Gambier, Ohio, U.S.A.;
William T. Litton, "Shaftesbury" Training Ship, Grays, Essex;
Alfred Noël Neate, C.E., 49 Fulwood Road, Aigburth, Liverpool;
Alexander Durie Russell, B.Sc., High School, Falkirk, Scotland;
John James Steward, F.R. Met. Soc., 457 West Strand, W.C.;
Lewis H. Tamplin, F.R. Met. Soc., Indo-China Steam Navigation Company, Wuhu, China; and
David Wylie, Whewell House, 9 East Road, Lancaster,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:

Brandon T. Brierley, F.G.S., Assoc. Mem. Inst. C.E., Linthwaite, Delph, Yorks (proposed by G. Calver);

rice Farman, Observatoire de Chevreuse à Jagny, par
ampierre (Seine-et-Oise), France (proposed by Camille
lammarion);
e Venner Merrifield, B.A., Head Master, Nautical
ollege, Byrom Street, Liverpool (proposed by W. H.
esant);
Molloy, M.A., Lützen, Glenageary, Kingstown, Dublin
proposed by Louis G. Macrory);
d Edward Nicholls, Principal of King Edward VII.
autical School, London, E. (proposed by Sir Howard
rubb); and
Wearing, Garsdale, Sedbergh, Yorks (proposed by
homas Weir).

-six presents were announced as having been received
last meeting, including, amongst others:

. S. Ball, A Popular Guide to the Heavens, presented by
shers; Royal Observatory, Greenwich, 17 charts of the
phic Chart of the Heavens, presented by the Observa-
Hasselberg, Untersuchungen über die Spectra der

facts we must not forget that older and at least equally well established ones cannot be ignored, and these do not support the theoretical views which are brought forward by Mr. Maunder.

W. G. Adams and Ellis have shown that the first shock of a magnetic storm is felt simultaneously at widely separated stations of the Earth's surface, but the more detailed examination of Adolph Schmidt* has proved that the disturbing vectors in different localities are by no means parallel to each other. Nor do they at all agree with that distribution of magnetic force which would result from the motion of electric particles projected from the Sun across the Earth's path. The disturbance in reality suggests that its cause is to be found in closed ring systems of electric currents lying parallel to, and not far above, the Earth's surface, systems which are very similar to those producing the diurnal variation of the magnetic forces. There is also other evidence tending to show that the seat of the disturbance is in our atmosphere, such as the fact, well established by Ellis, that magnetic storms occur more frequently near the equinox. In fact the whole behaviour of magnetic storms, as well as the suddenness of their first impulse, is quite inconsistent with the view that they are due to the electromagnetic effects of projected particles. We may, I think, accept it as proved that their primary cause is mainly of terrestrial origin. This view is in accord with the results of Lord Kelvin's calculation on the energy which would have to be supplied by the Sun if magnetic storms were due to electromagnetic waves emanating from that body. Lord Kelvin has never published the details of the calculation, but these are easily supplied. The outer magnetic field due to a uniformly magnetised sphere of radius a has an energy equal to $M^2/3a^3$, where M is the magnetic moment of the sphere. Such a sphere exerts its greatest force at points in the magnetic axis. Let us then take the most favourable position for the direction of magnetisation, and imagine the Sun to become a magnet with one of its poles pointing straight towards the Earth. The magnetic force H on the Earth's surface would be $2M/r^3$, if r is the distance between the centres of the two bodies. Expressing M in the terms of H, we find for the energy of the magnetic field outside the Sun's body $H^2r^6/12a^3$. Substituting numerical values ($r = 214R$; $a = \cdot 7 \times 10^{11}$; $H = \cdot 0005$) we find $\cdot 69 \times 10^{39}$ ergs for the amount of energy. In the particular storm discussed by Lord Kelvin the change of ·0005 in the magnetic force took place in the course of twenty-five minutes; the average work done per second is found by dividing the total energy by 1500, thus giving $\cdot 46 \times 10^{36}$ ergs per second. This is about one-third of the value given by Lord Kelvin, but the discrepancy may easily be due to a difference in one of the suppositions made. If we had, *e.g.*, imagined the axis of solar magnetisation to stand at

* *Meteorologische Zeitschrift*, vol. xvi. p. 385 (1899).

gles to the ecliptic the work to be done would be four great, and a further increase would result from taking netic field within the solar surface into account.

Maunder endeavours to get over the very formidable which Lord Kelvin's calculation has raised against any which makes the Sun responsible for the energy of storms, by supposing this energy to radiate only along anating from certain restricted regions of the Sun's But, apart from the fact that a radiation of electro- waves in restricted directions is impossible, the supposi- s not help him, because the radiating surface would be ed in the same ratio as the total amount of energy. Lord *reductio ad absurdum*, following from his calculation that e portions of the Sun's surface would, in a moderate storm, ring eight hours as much energy as the same portion lar surface does during four months in its regular supply nd light, would still remain. It may be urged that the r theory which is apparently favoured by Mr. Maunder lates quite a different propagation of energy from that derlies Lord Kelvin's calculation. That is quite true, not possible to calculate the energy supply on the theory ted particles, because that theory leaves all energy con-

length of the period) it could only happen in exceptional cases that one should take place within a few hours of the same phase in three or more successive periods. I have convinced myself of this by taking periods slightly differing from that of the solar rotation and examining their periodic recurrence. We may, therefore, accept it as proved that magnetic storms show some kind of periodicity, the length of the period being somewhere near 27·27 days. Looking at the matter without any preconceived opinions at all—and a preconceived opinion formed on previous knowledge is quite legitimate—Mr. Maunder's work does not necessarily compel us to admit that this period is due to solar influence. The sidereal and anomalistic months, for instance, have periods which are so nearly equal to that of the Sun's rotation that for a period of two or three rotations a lunar action could not be distinguished from one due to the Sun, and Mr. Maunder's results are quite consistent with the view that the active body is the Moon and not the Sun. The solar action may be more probable, owing to the undoubted connexions already established, but speaking purely of the conclusions which can logically be drawn from Mr. Maunder's statistics independently of other arguments the possibility of lunar action is equally indicated.

In order to clear up my own ideas on the point I have applied a method which I have already advocated and used in several publications. If a number of events like earthquakes or magnetic storms are arranged in any period whatsoever, we may calculate the coefficients of the periodic series which, according to Fourier, completely represents the succession of events. If the events are quite unconnected we may calculate independently the expectancy of the Fourier coefficients and the probability that any particular coefficient should exceed a given amount. If there are m events, and the value $1/m$ is given to each, so that their total sum is numerically expressed by unity, and if, further, a and b represent the two coefficients belonging respectively to the cosine and sine of any arbitrarily assumed period, the expectancy of a^2+b^2 is $4/m$, and the probability that a^2+b^2 should be greater than $4k/m$ is e^{-k}. The quantity a^2+b^2 I call, for shortness, the intensity of the particular period. These results hold only on the supposition that all events are quite independent. If there is a real period which affects them, then for this particular period we shall, if m is sufficiently large, obtain a coefficient substantially larger than the expectancy, and the method supplies, therefore, a criterion for such a real periodicity. But in the case contemplated by Mr. Maunder no real periodicity is suggested by him, but only the probability of the recurrence of the event after a certain length of time. I foresaw this case in my first publication on the subject,* and showed that here also the squares of the

* *Terrestrial Magnetism*, vol. iii. p. 13 (1898).

'ourier coefficients would be increased by the recurr
agnetic storms were to occur always in groups of two,
y a definite interval, the expectancy of the intensity
oubled for all periods which are multiples of the interv

In Table I. I have collected the results obtained
Ir. Maunder's list of magnetic storms and taking t
iven by him for the commencement of the storms. A
hese times in periods, there is no difficulty in obta
'ourier coefficients by well known processes. The firs
ives the period chosen, while the second column con
alues of the intensity belonging to this period. If
eriod equal to one-half that given in the first column
he corresponding squares of amplitude as given in
olumn; similarly the next three columns give the
$^2+b^2$, where the period is the nth part of that given in
olumn, the number being placed at the head of each
'hese mean values of the different columns and rows
iven, and finally the expectancy for each period.
umber taken account of was 270, and hence the expe
$\frac{4}{70}$.

Table II. gives similarly the results when the perio

There is, then, no evidence of a period depending on the lunation, but the interpretation of Table I. is somewhat perplexing. Leaving for a moment the period of 27·278 days out of consideration, the average square of the amplitude is ·0143, which agrees closely with the expectancy calculated on the supposition that magnetic storms are distributed quite at random without any relation to solar rotation. But the period temporarily omitted alters the aspect of the question. Were we to look at this table from the purely statistical point of view we should be justified in concluding, with some degree of probability, that there is a definite period of $\frac{1}{2} \times 27{\cdot}278 = 13{\cdot}64$ days in the breaking out of magnetic storms; for the ratio of the actual to the expected intensity is 5·9, and the probability of the accidental occurrence of this ratio is three in a thousand. This, of course, is not sufficient for anything amounting to a proof, but it gives at any rate a certain presumption in favour of a real connexion. It is certainly remarkable that for four out of five of the coefficients calculated the amplitude is greater than what is to be expected on the supposition of a random distribution. A closer examination of the numbers from which the Fourier coefficients have been derived shows that the period of 13·64 days is due to the fact that during certain parts of the twenty years examined storms were apt to occur in greater quantity when the longitude of the Sun's centre was somewhere between 55° and 90°, and that at other times the occurrence predominated when the longitude of the Sun's centre differed from the above by about 180°.

According to Mr. Maunder's view that a magnetic storm, whenever it occurs, is apt to be followed by another storm at intervals of time which vary according to the particular solar latitude which determines the storm, the expectancy for the intensity of all the periods in Table I. should be raised.

The table, as far as it goes, does not support this view. Nevertheless it cannot be said that there is a definite contradiction to it. We have, in fact, the choice between two interpretations.

1. Magnetic storms are apt to occur at times which, starting from a certain point, are multiples of 13·64 days. During some years the odd multiples, and during other years the even multiples, are principally concerned.

2. Magnetic storms often recur after several successive intervals which are equal to some lapse of time sufficiently near 27·28 days to fall within the limits of rotation of the sun-spot zones.

The first alternative is that more directly indicated by the above reduction of observations. It would explain all results obtained by Mr. Maunder, but its acceptance would involve the necessity of believing in the existence of some definite period equal to 27·28 days. As different sun-spot zones rotate with different velocities this would mean either that sun-spots have nothing to do with the phenomenon or that only the sun-spot

ving that particular time of revolution are concerned.
also mean that the activity is to some extent concen-
n definite meridians. There are great difficulties in the
ccepting this conclusion. On the other hand the second
ive, though it presents fewer theoretical difficulties, would
us to assume that the exceptional values of the coefficients
eriod of 27·278 days is accidental. If we accept the
lternative, and take the mean of all intensities collected
II. as the expectancy which corresponds to periods equal
nately to the solar rotation, I calculate that the proba-
an accidental occurrence of an intensity of ·0878 is ·009,
y one in a hundred. In twenty trials we should have,
e, obtained a number which on the average should only
ce in a hundred trials. The probability that the average
bservations should be ·0366 is about one in twenty-one,
e natural course of calculation we should find that, by
he average of five intensities, we should get one case in
one where its value is equal to or greater than the
found. In our trials we have actually found one case
ur. The possibility of accident is, therefore, considerable,
curious fact that it is just that one period which corre-

turbing field taken by itself alone. We express that field in terms of its spherical harmonic components, and may therefore write outside the shell

$$=\frac{A_n a^n S_n}{r^{n+1}},$$

inside the shell

$$=\frac{A_n r^n S_n}{a^{n+1}}.$$

In these expressions a is the radius of the Earth, r the distance from the centre of the Earth, A_n a constant, and S_n a surface harmonic of degrees n, being of the form

$$\cos\sigma\phi\,\frac{d^\sigma P_n}{d\mu^\sigma},$$

where P_n is the zonal harmonic of degree n and μ the cosine of the colatitude.

Substituting in the integral we easily find for the energy of the whole field

$$E=\frac{2n+1}{8\pi a^3}A_n^2\int S_n^2 ds,$$

and finally making use of well known properties of spherical harmonics

$$E=\frac{(n+\sigma)\,!}{(n-\sigma)\,!}\;\frac{A_n^2}{4a}.$$

If $\sigma=0$ the expression is to be doubled.

For the sake of simplicity consider the horizontal magnetic force at a point of the equator (referred to the axis of reference). Its maximum value lies north and south when $n-\sigma$ is odd, and east or west when $n-\sigma$ is even. Its intensity H may be expressed in the form

$$Ha^2=kA_n,$$

where k is a numerical factor.

The energy of the field in terms of H is

$$E=\frac{(n+\sigma)\,!}{k^2(n-\sigma)\,!}\;\frac{a^3H^2}{4}.$$

Table III. gives the values of $(n+\sigma)\,!/k^2(n-\sigma)\,!$ when n is three or less.

Table III.

n	1	2	3
1	2	...	...
2	[illegible]	[illegible]	...
3	$\frac{16}{3}$	$\frac{30}{225}$	$\frac{16}{45}$

t an idea of the order of magnitude we may take the
1, $\sigma = 1$, so that the energy is equal to $\frac{1}{2}a^3H^2$. Apply-
o the case of the Earth, and to the same magnetic storm
above, in which H increased by ·0005 in twenty-five
we find

$$E = 3\cdot22 \times 10^{19},$$

the rate of doing work $2\cdot15 \times 10^{16}$ ergs per second, or
ion horse power. The power is equal to that required to
o metric tons of water in twenty-five minutes from the
to the boiling point of water. It is thus seen that,
he actual force measured by our magnetographs may
qual to the weight of one-hundredth part of a milligram,
work done in a general storm affecting the whole Earth
eously is very large indeed. The large numerical value
limits us, as far as I can judge, to three alternative
ions of the origin of magnetic storms.
r calculation of the energy required is based on the
on that the magnetic field is independent of others on
is superposed. But there may not be such an indepen-
ition to the existing magnetic forces, but only a change

3. We are now left with the one remaining source of energy, which is sufficient for our purpose. That is the *vis viva* of the Earth's diurnal rotation. In C.G.S. units that energy is expressed by 26×10^{35}. That this energy, if we can find means of applying it, is capable of maintaining magnetic storms may be shown by a simple calculation. Suppose that a storm, on the average, lasts in full force forty times the twenty-five minutes we have considered in the typical case, and that we have 100 such storms in one year. The energy drawn away from the Earth would gradually diminish its rotational velocity, but so slowly that after provision has been made for the supplying of magnetic storms during a million years the Earth, as a timekeeper, would then be losing at the rate of only one second per year. Even a layer of air, at atmospheric pressure of the tenth part of a millimetre thick, has an energy of rotation more than two thousand times greater than that required for the production of a magnetic storm lasting twenty-five minutes.

Having been led to what seems to be the only available source of energy we must try to form some idea as to the manner in which the frequency of the magnetic storms may be influenced from outside, while their primary cause lies within the terrestrial atmosphere. It is important for this purpose to keep in mind that the intensity of an electric current always depends on two things—electromotive force and resistance. The electromotive force must supply the energy, but the resistance of air is affected by outside agencies, such as corpuscular emissions or ultraviolet radiation. When I discovered, in 1887, that a gas may artificially be brought into such a state that it ceases to behave as an insulator even to the smallest electromotive force, I at once pointed out the bearing of this on some phenomena of terrestrial magnetism, and suggested, in my first publication on the subject, that the greater amplitude of the diurnal variation may be accounted for by the greater conductivity of the outer regions of the Earth's atmosphere when the number of sun-spots is great.* Returning to the same subject in the concluding portion of my Presidential Address to Section A of the British Association at Edinburgh, I further suggested that both the periodicity of sun-spots and the connexion between these spots and magnetic disturbances on the Earth may be due to a periodically recurring increase in the electric conductivity of the parts of space surrounding the Sun. Since then the possibility of corpuscular projections has been discovered. Such corpuscular projections do, in passing through gases, invariably increase the electric conductivities. Ultraviolet light acts in the same way, provided it falls on sufficiently large conglomerations of matter. Without forming, therefore, any very definite theory we may accept the view that there is some solar effect propagated in straight lines which may increase the electric conductivity of the atmosphere,

* *Proc. Roy. Soc.* vol. xlii. p. 371 (1887).

fore set a magnetic storm going without supplying its

ffects we must assume to be propagated in straight lines, urved rays are impossible to explain unless we assume matter in interplanetary space to give it permanent con- The curvature might result from an irregular distri- such matter, and would not, in that case, revolve with but curved rays are only required if we wish to connect he solar influence with sun-spots. For this supposition no necessity at present.

udden breaking out of a magnetic storm suggests the of the passage of an ordinary electric spark, which is by ultraviolet radiation or radioactivity. The electro- rce being supplied, no passage of electricity takes place s there is insufficient conductivity. A small quantity of brought into the neighbourhood of the electrodes may e necessary conducting power, and the spark then will ough the air gap.

s been shown that the Earth's rotation must supply the and this it can only do if the electric currents are by motion across the Earth's lines of force.

elative motion between any extensive portion of the

or less plausible guesses as regards the necessary mechanism, but the particular guess ventured upon by Mr. Maunder is not, I think, consistent with well established facts. I cannot, therefore, agree with his somewhat boastful claim that he has rendered clear what Lord Kelvin has called a "fifty years' outstanding difficulty." He has, no doubt, added a new fact and made an important contribution to the subject. He has given renewed interest to it and brought out the urgent importance of further investigation, but the mystery is left more mysterious than ever; the facts have become harder to understand and more difficult to explain.

Magnetic Storms and associated Sun-spots. By the Rev. A. L. Cortie, S.J.

The first and most important conclusion of Mr. Maunder's paper on "Magnetic Disturbances, 1882 to 1903, as recorded at the Royal Observatory, Greenwich, and their Association with Sun-spots" (*Monthly Notices, R.A.S.* vol. lxv. No. 1, 1904 November) is, that the origin of magnetic disturbances on Earth lies in the Sun, and not in any body or bodies affecting both. That is, that the Sun is the seat of the efficient cause of our magnetic storms, for evidently Mr. Maunder is not speaking of a mere condition. And the premisses for this conclusion are: first, that the magnetic storms mark out the synodical rotation-period of the Sun; and secondly, that what marks out the synodical rotation of the Sun must be caused by something in the Sun—this second premiss is implied, but not expressed, and is not necessarily true—therefore the cause of magnetic storms lies in the Sun. But the argument of Mr. Maunder is faulty, in that it omits at least one other alternative: namely, that both the magnetic storms on Earth, and the magnetic centres on the Sun associated with sun-spots, which are presented to the Earth at successive synodical rotations, may have a common cause which is neither on the Sun nor on the Earth. This latter alternative is consonant with the theory proposed by Father Sidgreaves in his memoir "On the Connexion between Solar Spots and Earth Magnetic Storms" (*Memoirs, R.A.S.* vol. liv. p. 91). For when two sets of connected phenomena are found regularly to concur, the logical conclusion is not necessarily that one is the cause of the other, but that either one is the cause of the other, or they have a common cause. It is this latter alternative of which Mr. Maunder has omitted to take account, and which renders his syllogism out of form. Therefore, even were he to prove his first premiss—namely, that magnetic storms mark out the synodic rotation-period of the Sun—up to the hilt, it would still not

gically that the cause of magnetic storms resides in

is no doubt that some positions of the Sun relatively rth are more favourable conditions, and perhaps even conditions of movements of the magnets, the "diurnal the declination magnet, the "annual inequality," the prevalence of magnetic storms at the equinoxes, are evidence of this. Nor, again, is there any doubt of the nexion of magnetic storms with the spotted area and f spots on the Sun. The laborious memoir of Father s (*loc. cit.*) and the papers of the Greenwich observers wn this to be true, taking the spots in detail. This is in addition to the statistical work of Mr. Ellis, which ated the close accord of the variations of diurnal range eclination and horizontal force magnets over a long years, with the curve of annual relative sun-spot as prepared by Professors Wolf and Wolfer. But the mination in detail of sun-spots and magnetic storms, Father Sidgreaves for the period 1881–1898, and by the the minimum years 1899–1901 (*Astrophysical Journal*, No. 4, 1902 November), has shown glaring exceptions neral agreement of spots and magnetic storms, which

hand, the curve of relative sun-spot frequency should not be almost identical for "quiet" and all magnetic days, which it is.

To come now to Mr. Maunder's major premiss, that magnetic storms mark out the synodic rotation period of the Sun, in at least fifty per cent. of the cases observed. The chief evidence for this statement is set forth in Table III. of his paper; and as it is impossible at present to examine every sequence set down in the table, it is proposed to take the first and the second, and incidentally the fourth and the twenty-third, as also the thirty-second, for more detailed criticism. This last sequence is selected because it is claimed, in the first place, that it connects six storms which occurred in successive synodical rotations of the Sun, and in the second place because it includes two magnetic storms which, as Father Sidgreaves pointed out occurred at an epoch of minimum solar activity, when the Sun had been almost absolutely free from spots and faculæ for a considerable period. Table A of Father Sidgreaves' paper (*loc. cit.* p. 93) gives an example of the method in which the relation of sun-spots and magnetic storms was studied at Stonyhurst; and if the various sequences of Mr. Maunder's paper are studied in relation to the spots with which they were presumably connected, it will appear doubtful, whether the sequences in many cases might not be purely fictitious, so far at least as they are associated with sun-spots.

The first sequence in Mr. Maunder's list is connected with groups 53 and 53a of the Stonyhurst series, the life-history of which is given in the annexed chart. It is well to state here that the materials which have been utilised in the present discussion were prepared by Father Sidgreaves for his memoir. A summary history of these groups is also to be found in my paper on "The Duration of the Greater Sun-spot Disturbances for the Years 1881–99" (*Monthly Notices*, *R.A.S.* vol. lx. No. 8), the numbers of the groups here discussed tallying with those in Table I. of that paper.

These two associated groups, one being the recurrence of the other, persisted for five solar rotations. During the first rotation there were five days which were magnetically disturbed, the first storm occurring when the spot had just passed the central meridian. Four more days of magnetic disturbance occurred while the spot-group was on the invisible hemisphere of the Sun. During the second rotation there were only two magnetic storms: one did not coincide with any of the five days of magnetic disturbance of the first rotation, the other did. Surely such a coincidence is merely accidental. However, there is this fact in favour of a real synodical rotation coincidence, that the two storms that did coincide were the greatest of the whole series. Let it be supposed then that these two storms, one of the first and the other of the second rotation, mark out a magnetically active region of the Sun associated with the sun-spot. The sun-spot group returned

			W.							Cl.		Stony-hurst.	Green-wich.
3	14	15	16	17	18	19	20	21	22	23	July	53	2581.
5.			11.*	8			3						
5	11	13	4										
8	9	10	11	12	13.	14	15	16	17.	18	Aug.	53	2611.
				9*									
4	5	4	4										
4	5	6	7	8	9	10	11	12	13	14	Sept.	53.	2643
3	2	2	2	1									
2	3	4	5	6	7	8	9	10	11	12	Oct.	53.	2675
								3		3			
2	1	1	1										
9	30	31	1	2	3	4	5	6			Nov.	53a	2718.
						6							
1	1	0·4	0·1										

aunder, 151, 154, 156.

3 ; long. 91°, lat. +11°.
3a ; long. 94°, lat. +11°.

CHART II.

Sun-spot Group 29 and Associated Magnetic Disturbances. Sequences II., IV., and beginning of XXIII.

1886.		Cl.							R.						C.						W.							Cl.		Spot Number. Stony-hurst. Green-wich.
Mar.			23	24	25	26	37	28	29	30	31.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	April	29. 1861
M.			3						10	7	5.											†3	3	3	4			3		
S.									0·3	0·4	0·4	1	1	2	2	2	2	3	1	1										
Apr.			18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	May	29. 1878.
M.			3	3																			†6	3	3	3				
S.														1	1	2	8	9	9	10	9									
May		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	June	29 1884
M			3																											
S.									3	4	4	4	3	3	4	3	3	3	3	3	2									
June		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	July	29. 1897.
M.													3								*									
S.									3	3	2	2	2	1	1	1	1	1	1	0·2										
July	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31.	1	2	3	Aug.	29. 1906.
M.																					7*									
S.									0·4	1	2	4	4	5	5	6	4	5	3	2										
Aug.			4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Aug.	29. 1915.
M.													3									4*								
S.										1	1	1	1	1	1	1	1	0·4	0·2											
Aug.	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18									Sept.	29. 1924 1925
M.										§3	3	3			3															
S.											0·4	0·4	1	1	1	1.														

Reference numbers of disturbances: Maunder *, 72, 73, 74. † Numbers 69, 70. § 75. Mean heliographic coordinates, long. 71°, lat. −10°.

ree more rotations, diminished in size it is true, and the
tic centre ceased to act. And yet in other cases, notably
se of 1889 November, we are to suppose, in order to form
ence, that a magnetic centre can be active, not only during
e-history of a sun-spot group, but long after all spots to
the magnetic centre of storms have disappeared. This is
lous. Moreover, though this particular sun-spot group was
ished in size, it could still be magnetically active, on the
sition that these sequences of magnetic storms were con-
l with the sun-spot, for in the fourth rotation, when it
to the E. limb, another active storm occurred (omitted
Mr. Maunder's list), which forms an equally good sequence
No. 156 of his Table I.—which occurred at the fifth appear-
f the region of the spot on the E. limb—as is formed by
ers 151 and 154, marking the W. limb position. On the
sition of a stream-like set of particles emanating from the
nd impinging on the Earth to cause sequences of magnetic
s, it is difficult to imagine how both an E. limb and a W.
as well as a central, position of the spot, could be effective.
second sequence, too, seems to accentuate the non-activity
region of the first sequence during the third and subse-
rotations. It fact it would seem that the magnetic

should have been quiescent for five rotations, to break out again when all spots had disappeared. Mr. Maunder in his paper appeals to intermittent action both of spots and magnetic storms, and gives examples of the one in Tables IV. and V., and of the other in Table VII. This appeal to intermittent action would have been stronger had he been able to show that the intermittent magnetic storms were associated with intermittent appearances of spots. The life-history chart of the present solar disturbance contains two other sequences, viz. II. and IV., of Mr. Maunder's paper. Sequence II. is marked by three storms, according to his enumeration, but by two only according to the Stonyhurst lists, which are determined by W. limb position of the spot. Here again one sequence marks the W. limb position, and another the E. limb position of the same spot region, and the same difficulty occurs, as was mentioned above, of a stream of particles in practically parallel lines, derived from the same active magnetic region, reaching the Earth when the spot was both on the E. and W. limbs. Sequence IV., also of two members, occurred when the sun-spot group 29 was on the invisible disc of the Sun, but the first member of the sequence is accredited to a sun-spot group, No. 28 of the Stonyhurst lists, which was visible for six successive rotations, and the second member probably belonged to a different sun-spot group altogether, No. 30 of our lists, which was visible for three rotations. Hence this concurrence to form a sequence seems to be fortuitous. There is also in this chart of group 29 a sequence of three magnetic storms which are not in Mr. Maunder's lists, and which are unconnected with any of the greater sun-spot groups of the year 1886. The result again of the study of the sequences associated with the life-history of this group serves to show, that although sequences undoubtedly exist, the nature of their connexion with the spot-groups, which are presumed to be indices of the regions of magnetic activity on the Sun, is not that of streams of particles of restricted diameter.

The sequence numbered XXXII. in Mr. Maunder's table is important, first, because it contains six members, and secondly, because it occurred at a time of minimum activity. By this sequence Mr. Maunder endeavours to connect the active magnetic storms of 1889 November with the second rotational appearance of the biggest spot of the year which was first seen on June 16. But in his table on p. 21 the longitude of the centre of the Sun's disc has altered from $57^\circ{\cdot}0$ at the beginning of the sequence to $108^\circ{\cdot}8$ at the end of the sequence. This in itself is internal evidence that the members of the sequence are only fortuitously connected, and do not mark the same magnetic region on the Sun. On pp. 29 and 30 Mr. Maunder discusses the life-history of the groups on the Sun when the first of these disturbances appeared. But besides the two groups of spots he mentions in longitude 35°, latitude -7°, and longitude 82° and

—8° respectively, there was a third group, Stonyhurst 42, which was on the central meridian four times, the ch numbers of the spots being 2097, 2100, and 2102, 2103, each successive rotation. It is with this spot-group that n of October 5—the fourth of the sequence—was certainly d, the mean heliographic coordinates of the group being e 156°, latitude −22°. There is also quite a possibility of nd and third members of the sequence having belonged me spot-group. However this may be, the attempt to the November magnetic storm with the one great spot of the year breaks down. The spots are separated 120° ude, and do not mark the same magnetic centre. In nyhurst lists the several storms of this sequence are ed to three spot-groups, No. 40, long. 35°, lat. −7°, long. 82°, lat. −8°, No. 42, long. 156°, lat. −22°. The ive longitudes of these three groups must be noted, which the similar progressive longitude of the centre of the isc for the various members of sequence XXXII., and e shows that they belong to different sun-spots. Mr. r has failed to catalogue an active magnetic storm of vember 17, which would give a storm occurring between and sixth members of the group when the same was turned directly away from the Earth. It makes ence less strong than it would otherwise have been. with regard to this particular sequence Mr. Maunder *oc. cit.* p. 23) that it is one of those that indicate a much

streams of particles, practically parallel, and of relatively small diameter impinging on the Earth is negatived. Such a stream of particles could not be effective at positions so remote from each other as the E. and W. limbs of the Sun.

Stonyhurst College Observatory,
January 1905.

Observations of the Spectra of Sun-spots, Regions C to D.

By A. Fowler.

Introductory.

The observations of the spectra of sun-spots forming the subject of the present paper were made somewhat irregularly during the period 1903 October 15 to 1904 December 31 Detailed observations of widened lines were made on twenty-three separate days, and fifty-three observations of the appearance of the C line in and near spots were made on thirty-five days. The observations were restricted almost exclusively to the red end of the spectrum between C and D_2, and as many as possible of the affected lines in this region were recorded. They are therefore comparable with the observations made by Father Cortie at Stonyhurst,* and the results are of some interest as showing the degree of agreement between two independent observers working on essentially the same plan. It is possible also that some points in the discussion of the observations which I have attempted may be suggestive to other observers.

Mode of Observation.

All the observations were made with an "Evershed" two-prism solar spectroscope by Hilger, attached to the 6-inch Troughton equatorial provided for the instruction of students at the Royal College of Science, South Kensington. The definition of the spectroscope is remarkably good, and the dispersion is adequate for the identification of most of the lines. There are of course many close doubles which cannot be clearly resolved with this equipment; but if such were widened the affected component could often be judged by noting on which side the widening seemed to lie; in other cases it remains doubtful which of the components was affected.

The approximate positions of the lines were read off from Rowland's map in the usual manner, and were afterwards corrected to two places of decimals by reference to the tables of solar lines.

* *Mem. R.A.S.* vol. l. pp. 30–56; *Monthly Notices*, vol. lxiii. pp. 468–480. Summarised in *Astrophys. Jour.* vol xx. pp. 253–265.

difficulty was found at first with regard to a suitable
which to indicate the amounts of widening of the lines.
Cortie's method is to state the extent of widening in
the normal width of the corresponding solar line, but I
extremely difficult to assign numbers on this plan to
ch are very feeble in the Fraunhofer spectrum ; there is,
, the objection that the unit of widening is different for
lines. I therefore decided provisionally on a simple
ging from 5 for the lines most obviously widened and
l to 1 for those in which the widening could only just
nised with certainty, hoping that the discussion of the
would eventually suggest some better system. The
assigned include the combined effects of widening and
g and directly indicate little more than the relative ease
tion. Towards the end of the series of observations, as
d later on, it was concluded that the most useful method
ling the lines is to note the actual intensities of the spot
comparison with neighbouring solar lines outside the
trum.

ly rarely happened that the whole of the region C to D
minutely examined in a single observation, so that
only the principal lines throughout this part of the

hofer lines are usually present, and there are, in addition, "spot bands," some of which were also observed. There is also the "continuous" absorption, but the dispersion employed was insufficient to show the breaking up of this into closely adjacent fine lines which has been noted by Young and Dunér.

The first column of the table gives the wave-lengths of the affected lines, as taken from Rowland's tables.

The origins of the lines are indicated in the second column, these, with few exceptions, being as assigned by Rowland. Photographs of the spectra of vanadium and titanium which I have taken on plates stained with pinachrome show a few additional lines of these elements; but as the wave-lengths need confirmation with higher dispersion, possible origins depending upon them are noted in the column of Remarks. Apparent coincidences with telluric lines are not included as origins, but are also indicated in the column of Remarks.

Column 3 shows the number of times each line was observed. The greatest number is eighteen; but, considering the nature of the records, it is not to be supposed that the lines noted on fewer occasions were necessarily not affected when not recorded.

Column 4 indicates the mean "widening" on the arbitrary scale which has already been mentioned. The numbers derived directly from the observations have been multiplied by 2, in order to reduce them to the more convenient scale which gives 10 for the maximum.

Column 5 gives the ordinary intensities of the lines in the Fraunhofer spectrum according to the estimates of Rowland. A line of intensity 1 is clearly visible on the map; and below this the lines, in order of faintness, proceed from 0 to 0000, indicating lines more and more difficult to see.

Besides the references to coincidences with telluric lines and probable coincidences with previously unrecorded lines of vanadium and titanium, column 6 contains a few general remarks, and also indicates by a † the lines which do not appear in Father Cortie's summary of the Stonyhurst observations. Closely adjacent lines, observed by Cortie in some cases, are indicated by a wave-length following the †.

TABLE I.

Widened Lines between D and C.

Wave-lengths.	Probable Origins.	Number of Observations.	Relative Mean Widening.	Intensity in Sun.	Remarks.
5890·19	Na	10	7	30	D_2
95·16	...	4	3	0	A wv *
96·16	Na	10	7	20	D_1
98·38	...	2	4	4	A wv *
99·52	Ti	8	6	1	

* Indicates that the line is not in Cortie's table.

Wave-lengths.	Probable Origins.	Number of Observations.	Relative Mean Widening.	Intensity in Sun.	Remarks.
›00·14	...	1	5	2	A wv
›00·26	...			4	A wv
›03·75	...	8	5	1	A wv *
11·37	...	1	7	0000	*
13·21	...	1	4	3	A wv *
15·65	...	4	4	1	A wv
16·48	Fe	8	5	3	*
18·77	Ti	12	7	0	* (18·64 A wv)
22·33	Ti	10	5	0	* (22·74 A wv)
23·87	...	1	6	1	A wv *
32·31	...	1	4	5	A wv
38·27	...	16	7	0	A wv. Possibly Ti
41·99	Ti	8	8	00	* (41·85 A wv)
44·95	...	7	6	1	A wv
49·57	Fe	3	6	1	
[illegible]	Ti	[illegible]	[illegible]	[illegible]	

Wave-lengths.	Probable Origins.	Number of Observations.	Relative Mean Widening.	Intensity in Sun.	Remarks.
6054·29	...	2	5	00	A ? *
57·48	...	1	4	00	
58·39	...	5	6	000	* Possibly V
63·08	...	15	6	0	"Much widened always (Cortie)
64·85	Ti	17	7	00	
81·67	V	18	7	0	
82·93	Fe	1	4	1	
84·33	...	1	4	0	*
85·47	Ti, Fe	18	6	2	
86·50	Ni	1	4	1	
88·05	...	2	4	00	
90·43	V	15	6	2	See Note (1)
91·40	Ti	2	4	0	
93·86	Fe	1	2	2	
98·47	...	2	3	0	
6100·49	...	1	4	00	
02·39	Fe			2	This group appears to be usually strengthened in spots. The Ca line is probably the most widened
02·94	Ca	7	6	9	
03·40	Fe			4	
11·87	V	16	8	0	* (11·29 Ni)
19·74	V	17	8	1	
19·97	Ni	1	4	0	
22·43	Ca	5	5	10	
26·44	Ti	16	7	1	
29·19	Ni	1	4	1	
35·58	V	15	7	00	Spot line possibly includes Cr 6135·99
45·23	...	1	4	2	
50·36	V	15	7	0	
54·44	Na	15	6	2	
56·24	...	1	4	00	
60·96	Na	3	6	3	
61·50	Ca			4	
66·65	Ca	3	2	5	
69·25	Ca	1	4	6	
69·78	Ca	2	5	7	
88·21	Fe	1	4	4	

* Indicates that the line is not in Cortie's table.

e- hs.	Probable Origins.	Number of Observations.	Relative Mean Widening.	Intensity in Sun.	Remarks.
20	Co	1	4	00	A wv? *
40	V	17	9	0	
90	...	17	7	00	Possibly Scardium. (2)
28	...	2	2	00	
08	V	2	5	000	*
36	Fe	1	6	5	
63	Ti			000	*
57	V	14	6	1	Attributed to V by Y seen in new photogr
01	Fe	5	5	0	Possibly Ti
55	Fe	3	5	00	
72	V	11	5	000	
44	Fe	4	5	1	
94	V, Fe	1	4	8	Strong compound line
86	Fe	1	4	3	

Wave-lengths.	Probable Origins.	Number of Observa-tions.	Relative Mean Widen-ing.	Intensity in Sun.	Remarks.
6287·95	...	1	4	1	A (O)
89·61	...	1	5	1	A (O) *
93·03	V	11	7	000	? * (92·38 ?)
96·58	V	12	7	0000	? * (96·17 A [O] ?)
6301·72	Fe	1	6	7	
04·55	...	1	3	000	*
06·02	...	16	9	2	A (O) "Generally much widened" (Cortie). Possibly due to Scandium. See Note (2)
18·24	Fe	1	5	6	
27·82	Ni	1	2	2	
30·32	Cr	13	6	1	This is the strongest red line of Cr
62·56	Zn	1	6	1	Said to be variable in Sun
63·09	Cr, Fe	7	6	2	
64·92	...	1	2	0	
66·56	Ti	6	6	000	
66·71	Ni			0	
81·6	...	5	...	...	"Spot band"
89·0	...	5	...	...	"Spot band"
92·75	...	3	3	0	
6400·22	Fe	1	4	8	
05·98	...	3	4	00	
13·80	...	4	5	oc oo	? *
25·08	...	1	6	00	
35·26	...	2	4	0000	*
39·29	Ca	8	6	8	
50·03	Ca	8	6	6	
52·54	...	3	5	00	
55·23	Co	5	5	0	
55·82	Ca	8	7	2	
62·78	Ca	9	6	5	
62·97	Fe			3	
63·97	...	1	4	0000	A ? * (63·72 ?)
64·90	...	6	5	00	
71·89	Ca	12	6	5	
91·88	Mn	1	4	000	

* Indicates that the line is not in Cortie's table.

a.	Relative Mean Widening.	Intensity in Sun.	Remarks.
	6	6	
2	6	8	
2	5	4	
2	5	0	A wv *
6	6	00	A wv * (08·83?)
2	4	2	A wv
1	6	6	
4	6	0	*
1	6	1	*
53	...	40	See Note (4)

Notes on some of the Lines.

. In his preliminary table Rowland assigned this line to Fe, corrections" it was amended to Ti, V. My photographs show of V apparently coincident with 6090·43, while titanium shows a rate intensity which appears to agree with 6091·40. Mitchell *Journ.* vol. xix. p. 358) assigns the former to Fe, V ?, and the

.

·90 and 6306·02. These lines were always widened, and are very ue to scandium. According to Thalén, the two strongest lines of in the red are 6210·0 (intensity 8) and 6304·0 (intensity 10), which come 6211·0 and 6305·1 when corrected to Rowland's scale. The s between these and the spot lines are not greater than others which found in Thalén's observations as compared with Rowland's. The ation is the more probable, as scandium lines have been noted among idened lines in the region more refrangible than D, notably, 5672·05. tant that the wave-lengths of the red lines of scandium

are weak in the Sun (000 and 1 r not been able to dete Rowland attribu eleme

Comparison with Stonyhurst Observations.

Of the 146 lines contained in the foregoing table of spot lines 109 appear also in Cortie's list, 9 others are probably common to the two, and 28 were not observed by Cortie. Several of the lines not seen by Cortie, or for which slightly different wave-lengths are given, are due to vanadium and titanium, and in view of the presence of so many other lines due to these elements they might be expected to appear in the spots.

Nearly 200 lines recorded by Cortie do not appear in my table, but the great majority of these were only noted as slightly widened. Only 14 of them had a mean widening of 10 or more on Cortie's scale, and even these were seldom observed; 7 of them in fact were only recorded once, 3 of them twice, 1 three times, 1 four times, and 2 six times.

It is probable that the greater number of lines in Cortie's table is to be chiefly accounted for by the fact that his observations include all phases of the sun-spot cycle, whereas mine only cover a short period preceding a maximum. Many of the additional lines are due to iron and nickel, and Cortie states that his observations "confirm the fact that the iron lines, while not displacing other faint lines, are more affected in minimum than in maximum spots."

There is a difference of another kind between the two sets of observations: namely, that in spite of the much smaller total number of my observations, some of the lines were more frequently recorded than at Stonyhurst. The majority of such lines are due to vanadium, 6090·4, for example, being only once recorded by Cortie, as against 15 times by myself. The chromium line 6330·3 is another notable example, having been only twice recorded by Cortie, while I have never missed it when this part of the spectrum was examined in sufficient detail.

These differences, as well as some of those previously mentioned, might conceivably be explained by supposing that the lines of vanadium, titanium, and chromium were generally more strongly developed during the period covered by my observations than in the Stonyhurst period. It is more probable, however, that they are to be accounted for by the difficulty of making complete records of the affected lines when a large region of the spectrum is undertaken.

The agreement between the two series of observations, so far as they are comparable, may be considered very satisfactory on the whole.

Interpretation of Widened Lines.

In attempting to interpret the sun-spot spectrum there is no obvious reason why we should depart in the first instance from the ordinary methods of spectrum analysis. Many of the

ristic lines are undoubtedly due to familiar elements, en perfect observations, it should not be difficult to ie the conditions under which the corresponding vapours spots unless altogether outside our laboratory experience. istance, the vapours are at a temperature not greatly from that of the vapours which produce the Fraunhofer might be expected that the relative intensities of the a given element in spots would be the same as those of esponding lines in the arc spectrum of the element; while nperature were very different, the intensities of certain ıld be changed in accordance with experimental results.
this point of view it would appear that what is needed bservations is not so much a record of the amount of of the various lines as of their actual intensities in the tra. The widening of a line may, in fact, generally be as an intensification such as would be produced by an in the thickness and density of the absorbing vapour.
most convenient scale for representing the intensities of lines is furnished by Rowland's estimates of the Fraunes, and I have accordingly aimed at reducing my obserso as to indicate the intensities of the widened lines on scale. For this purpose several observations of lines of intensities were made in which the spot line under ion was compared with neighbouring Fraunhofer lines the spot spectrum and the equivalent solar intensity obtained. The line 6243·3, for example, reaches an in-

support from the discussion of the spot elements which are only represented in the Sun by comparatively faint lines—namely, vanadium, titanium, and chromium. The nature of the evidence will be sufficiently gathered from the part of the titanium spectrum illustrated in fig. 1. The upper spectrum indicates the relative intensities of the Ti lines in the Sun according to Rowland; the middle spectrum shows my own estimates of the intensities of the lines in the arc spectrum, and the lower one indicates the equivalent solar intensities of the lines in spots, determined partly by direct observation and partly by interpolation as already explained. (The line 6085·47 in the Sun is compounded of iron and titanium, and the solar intensity due to the latter is indeterminate.)

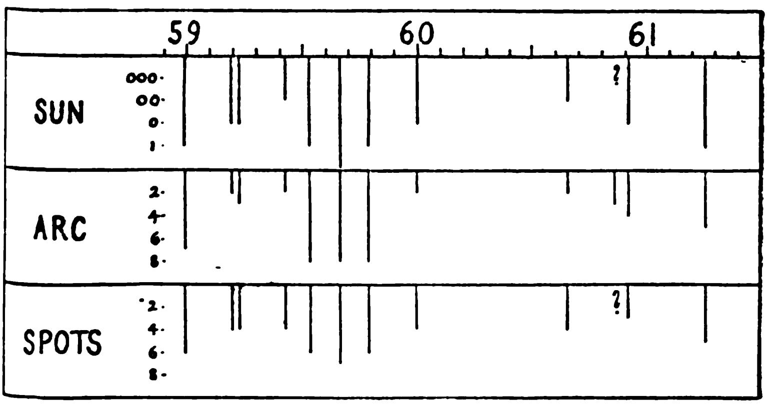

Fig. 1.—The relative intensities of titanium lines in spots compared with the intensities in arc and Sun.

It will be seen that the relative intensities of the lines in spots are in fair agreement with those in the Sun and arc, and the comparison therefore suggests that all the lines of titanium in spots are strengthened in proportion to their intensities in the Sun. Cortie has, in fact, already noticed that the most widened lines of titanium are among the brighter lines due to this element.*

Similar results are obtained for vanadium; and in the case of chromium, which only shows three faint lines in this part of the spectrum, the strongest line in the spots is also the strongest in the arc spectrum. The observations of individual spots lead to the same conclusion, assuming that the occasional omission of lines may be attributed to the difficulty of making complete records.

In the case of spot elements which yield Fraunhofer lines of

* *Mem. R.A.S.* vol. l. p. 46.

[redacted] fferent intensities, the weaker lines tend to appear rela-
[redacted] more widened" than the stronger ones, but it by no
[redacted] llows that this implies an inversion in the intensities of
[redacted] It is easy to show that, in photographs at least, a
[redacted] trengthening of all the lines belonging to an element
[redacted] a more obvious effect on the weaker lines than on the
[redacted] es, though all may be intensified in the same ratio. It
[redacted] ore probable that the widening of strong solar lines
[redacted] erally be under-estimated in comparison with that
[redacted] eaker ones, or even passed without record. In my own
[redacted] ons, for example, I have never included the strong
[redacted] ine 6162·39 (intensity 15 in Sun) among the affected
[redacted] ugh many other lines due to the same element were
[redacted] evertheless the fact that it has been very frequently
[redacted] by Cortie suggests that it was really widened at the time
[redacted] servations but was overlooked.

[redacted] ver, if intensities and not "widenings" be considered,
[redacted] ts for calcium and sodium are in accordance with those
[redacted] from the behaviour of the lines of vanadium, titanium,
[redacted] mium. The strongest lines in the spots are also the
[redacted] in the Sun and arc.

[redacted] bservations of the lines attributed to iron, nickel, cobalt,
[redacted] ganese are inadequate for useful discussion, but it is
[redacted] that lines of these substances were not much affected
[redacted] e period of observation.

Telluric Lines.

[redacted]

related,[*] and it is, therefore, very improbable that only isolated components would be widened if cool oxygen were really present. Further investigation of metallic spectra in the red end will doubtless throw additional light on this question.

The Spot Bands.

Four positions are mentioned by Cortie as marked by the occurrence of "spot bands," namely—

6150·36	Band at this position once.
6306·02	A band near here.
6380·96	Spot-band position.
6388·63	" "

In the case of the first two I have not recorded anything different in appearance from the ordinary widened lines, the first being due to vanadium and the second probably to scandium.

I have, however, recorded the remaining two as bands on five occasions, and my most satisfactory estimates of their wave-length are 6381·6 and 6389·0. They seemed to present the appearance of ill-developed flutings, degrading towards the violet, or of narrow bands sharper on the red side, but not extending more than one or two tenth metres. A somewhat different description is given by Mitchell,[†] who observed on 1904 April 15 that the region 6380 to 6400 was resolved into seventeen groups of fine lines similar in appearance to G under low dispersion.

In four of the spots showing these bands it was noted that the C line was neither reversed nor distorted, while in the fifth (1904 October 29) C was brilliantly reversed just outside the spot, but not in the umbra, where the bands were observed. All the spots in which the bands were seen were comparatively large and the widened lines strongly marked.

An inquiry into the probable origin of the bands has so far been fruitless. They seem to have nothing in common with the titanium flutings which are so characteristic of the Antarian, or third type, stars. Neither are any bands in corresponding positions found on my photographs of the banded spectra of vanadium, chromium, manganese, or iron.

Besides the bands in the red, I have also several times observed those in the region more refrangible than *b*, some of which were first recorded by Maunder, and have recently been photographed by Hale.[‡] So far as they go, my estimates of the positions of the bands are in good agreement with those of Hale, as will be seen from the following comparison :—

* Lester, *Astrophys. Journ.* vol. xx. p. 81, among others.
† *Astrophys. Journn.* vol. xix. p. 359.
‡ *Ibid.* vol. xvi. p. 220.

Hale.	Fowler.	Remarks.
5163·72 *nb*	...	...
5163·06 *d*	5163·0 *d*	Maunder 5163·3
5160·15 *d*	5160·2 / 5159·8	„ 5160
5157·86 *n*	...	...
5156·80 *t*	5157·2 / 5156·8	Maunder 5157·2
5150·03 *d*	5150·4 / 5149·9	...
5147·72 *d!*	5147·65 *n*	Ti line
...	5145·64 *n*	„ „
5144·03 *d*	5143·9 / 5143·5	...

n = narrow, *b* = band, *d* = double, *t* = triple.

rigin for these bands has been traced, but their occur-
pairs rather suggests a common origin.
iew of the possible relation of the sun-spot bands to the

Note on the Determination of the Longitude Paris-Greenwich in the Year 1902.

(*Communicated by the Astronomer-Royal.*)

In view of the discordance between previous determinations of the longitude of Paris-Greenwich, the International Geodetic Conference in 1898 expressed the view that a redetermination was desirable. It was arranged by M. Lœwy and the Astronomer-Royal that the redetermination should be undertaken in concert by the two observatories of Paris and Greenwich. Owing to the determination of the longitude Greenwich-Killorglin in 1898 and the eclipse expeditions of 1900 and 1901 it was not found practicable to commence this work till 1902.

The programme arranged in conjunction with M. Lœwy provided for the determination being made in two stages—in the spring and autumn of 1902. The instruments used were the four portable reversible transits belonging to the Royal Observatory which had been used in previous longitude determinations from 1888 to 1898. Each observer kept the same instrument throughout, taking it with him from Paris to Greenwich, or Greenwich to Paris. The instruments were distributed thus :—

Observer...	M. Bigourdan	M. Lancelin	Mr. Dyson	Mr. Hollis
Transit instrument	E	D	B	C

The observing stations at Greenwich were the Transit Pavilion and an adjacent wooden observing hut in the front court; the observing stations at Paris were in the grounds to the south of the Observatory and a little to the east of Cassini's meridian.

The French observers originally selected by M. Lœwy were M. Renan and M. Bigourdan, but owing to the illness of M. Renan he was replaced by M. Lancelin. The English observers were Mr. Dyson and Mr. Hollis.

Independent determinations of longitude were thus made simultaneously by the French and English observers, using adjacent stations and similar instruments. A double interchange of observers and instruments was made both in the spring and autumn. In the autumn the stands were also changed with the instruments. The programme of observations required clock-errors to be determined simultaneously at Greenwich and Paris on three, six, and three full nights respectively in the three parts of each determination. The following table gives details of the number of nights of observation of the English observers :—

Date.	Observer at		Signals Exchanged.	Number of Nights on which Clock-error was Determined			Weight.
	Paris.	Green-wich.		Paris.	Green-wich.	Simul-taneously.	
1902.							
r. 17–30	Dyson	Hollis	13 nights	5	9	4	7
. 6–24	Hollis	Dyson	19 ,,	10	11	6	12
. 23–May 3	Dyson	Hollis	7 ,,	3	5	3	6
t. 21–26	Hollis	Dyson	6 ,,	4	6	4	7
t. 29–Oct. 22	Dyson	Hollis	24 ,,	11	13	8	14
. 25–Nov. 4	Hollis	Dyson	11 ,,	8	8	5	8

complete programme for a full night's observations was ws :—

)bservation of mark and nadir.
*Micrometer E.** : Eight time stars, one or more polar stars, two or three observations of level.
Micrometer W. : Eight time stars, one or more polar stars, two or three observations of level.
)bservation of nadir.

usually depended on the mean of two or three observations with the micrometer East, and an equal number with the micrometer West. The effect on the clock error is $n(\tan\delta - \tan\lambda)$, where δ is the mean declination of the time stars and λ the latitude. Stars of high declination (but always south of the zenith) were used, so that the above factor is small. The accordance of the separate determinations of n shows that no appreciable error, systematic or accidental, can be attributed to this cause.

Clock-error.—The clocks used were the standard sidereal clocks of the two observatories, Greenwich and Paris. The rates were very uniform. The catalogue of stars used for determination of clock-error was prepared by M. Lœwy, the right ascensions being reduced to Newcomb's fundamental system. At the conclusion of the longitude determination corrections were deduced to the adopted positions of the stars from the combined observations of the French and English observers. These corrections were applied, but did not alter the resulting longitude by $^{s}\cdot001$. Incidentally the deduction of these corrections showed that the probable accidental error of the observation of a star transit was $\pm^{s}\cdot033$.

The Telegraphic Signals.—At each station the signals sent and received were recorded by means of the same relay and local circuit as the observations of transits. By the insertion of suitable resistance in a parallel circuit the current actuating the relay was made the same when recording the observations of transits and of signals received or sent. The time of transmission in one direction was found to be $0^{s}\cdot021$ from the mean of the spring determinations and $0^{s}\cdot022$ in the autumn. The differences from these means on individual nights were usually only a few thousandths of a second.

The following table exhibits the separate determinations of the difference of longitude between Cassini's meridian at Paris and that of the transit circle at Greenwich. The difference of the personal equation D – H was found to be $-0^{s}\cdot0421$ in the spring and $-0^{s}\cdot0425$ in the autumn. The value $-^{s}\cdot042$ has been adopted throughout and applied to derive column 3 from column 2.

e of Longitude between Paris and Greenwich.—Spring Determination.

	1902.	Determined Difference of Longitude.	Corrected for Personal Equation.	Weight.	Discordance from Mean $9^m\ 20^s{\cdot}977$.	Discordance from General Mean $9^m\ 20^s{\cdot}932$.
		m s	m s		s	
Paris / Greenwich	Mar. 19	9 21·060	9 21·018	2	+0·041	+0·086
	23	·108	·066	1	+0·089	+0·134
	25	·054	·012	2	+0·035	+0·080
	28	·096	·054	2	+0·077	+0·122
Paris / Greenwich	Apr. 13	9 20·979	9 21·021	2	+0·044	+0·089
	17	·966	·008	2	+0·031	+0·076
	18	·901	20·943	2	−0·034	+0·011
	20	·940	·982	2	+0·005	+0·050
	23	·922	·964	2	−0·013	+0·032
	24	·899	·941	2	−0·036	+0·009
Paris / Greenwich	Apr. 28	9 20·901	9 20·859	2	−0·118	−0·073
	May 1	·979	·937	2	−0·040	+0·005
	3	·977	·935	2	−0·042	+0·003

If the determinations in the spring and autumn are considered separately we find—

(Spring) Long. = $9^{\mathrm{m}}\ 20^{\mathrm{s}}\!\cdot\!977 \pm {}^{\mathrm{s}}\!\cdot\!0110$. Prob. error of full night = $\pm {}^{\mathrm{s}}\!\cdot\!039$

(Autumn) Long. = $9\ 20\!\cdot\!910 \pm \cdot0042$. Prob. error of full night = $\pm \cdot016$

The smaller probable error in the second series entitles it to greater weight, but the difference between the two determinations being so much larger than the probable errors would indicate, the two results were not combined with the relative weights given above. If the simple mean is taken $9^{\mathrm{m}}\ 20^{\mathrm{s}}\!\cdot\!943$ and the discordances formed from it, the probable error of a full night (weight 2) in the spring determination is found to be $\pm^{\mathrm{s}}\!\cdot\!051$, and in the autumn determination $\pm^{\mathrm{s}}\!\cdot\!037$. The autumn determination has therefore been given a double weight as compared with that in the spring, and the resulting value of the longitude is

$$9^{\mathrm{m}}\ 20^{\mathrm{s}}\!\cdot\!932 \pm {}^{\mathrm{s}}\!\cdot\!0060.$$

The discordances from this value are given in the last column.

The systematic difference between Parts I. and III. in the autumn determination is much smaller than in the spring. This is an additional reason for giving a double weight to the latter determination.

It does not seem possible that the systematic discordances shown in the separate parts of the two determinations can be attributed to instrumental errors. Variation of the personal equations of the observers is a natural explanation, and in support of this it may be noticed that the largest discordances are in Series I. of each of the determinations, especially of the one made in the spring. The observers' personal equations had possibly not settled down to the values they subsequently acquired. The advantage of the double exchange of observers and of a determination in the spring and the autumn is its effect on the elimination from the result of such systematic errors.

The value found by the French observers, MM. Bigourdan and Lancelin, is given in the *Comptes Rendus*, vol. cxxxix. p. 1014, as $9^{\mathrm{m}}\ 20^{\mathrm{s}}\!\cdot\!974 \pm {}^{\mathrm{s}}\!\cdot\!008$.

The results for the several determinations of the Paris-Greenwich longitude by the English observers are :—

	Longitude.	Prob. Error.
	s	s
1888	9 20·85	± ·018
1892	9 20·79	± ·022
1902 I.	9 20·977	± ·011
1902 II.	9 20·910	± ·004

Royal Observatory, Greenwich:
1905 *January* 11.

Temperature of Sun-spots and the Spectrum of an artificial one. By W. E. Wilson, D.Sc., F.R.S.

nost usual theory of the cause of the darkness of sun- that formulated by De la Rue, Stewart and others, spots are produced by the down-rush of cooler material photosphere ; and the fact most strongly insisted on in f this theory is that in the spectrum of a spot there are erable number of the Fraunhofer lines, both darkened ned.

hotograph reproduced on Plate 8 of what I have called the m of an Artificial Sun-spot," as I believe it will throw eal of doubt on the validity of the usual sun-spot theory, possibly go towards proving that in sun-spots we have of a higher temperature than the surrounding photo- nd not a cooler one.

photograph was obtained by the following experiment. globe surrounding an electric arc represented the Sun's ere. A small patch of thin paper on the globe, which

atmosphere is a good example of the effect of increasing thickness on the number of lines seen.

If a sun-spot is a region where the temperature is so high that the solid particles which form the photospheric clouds are turned into a gas, it—being then a bad radiator—would appear comparatively dark. It is of importance to remember that a sun-spot is only dark when compared with the dazzling brilliancy of the photospheric clouds, and is really about as bright as the limelight.

It has been argued that if a spot was a really gaseous region, and that it was deep enough to be opaque, it would radiate as a solid; but I think the suggestion made by the late Professor G. Fitzgerald gets over this difficulty. He said that in the Sun there must be in such a gaseous layer enormous convection currents, which would scatter a lot of the light coming from the lower layers, and in fact that it would never reach the surface, so that the general effect would be the radiation from a layer of gas not deep enough to behave as a solid, so that the spot would appear dark.

There seems to be a good deal of evidence that the Sun's photosphere is merely a rather thin cloud stratum the solid particles of which are carbon. In the first place we do not know any other substance that would remain in the solid form at the temperature of, say, 7000° C.; and from some experiments made by Fitzgerald and myself on the effect of high pressure in the gas surrounding an electric arc we came to the conclusion that carbon at the temperature of 3500° C. in the arc is not nearly at its boiling-point, as was generally supposed.

Another point which greatly strengthens the probability of the photosphere being carbon is the observation made lately by Hale. Using the large solar image of the Yerkes refractor, and placing the slit of the spectroscope tangentially as close as possible to the photosphere, he succeeded in seeing as bright lines both the yellow and green bands of the fluted spectrum of carbon.

This observation is, I think, of first importance in showing that in the photosphere we have carbon.*

That there should be a large quantity of carbon in the Sun also seems probable from the wide determination of it on the Earth. Its atomic weight would also give it a position with other gases that we know occupy this level.

Now is it not conceivable that at a certain distance below the photosphere the temperature may be so high that even carbon is volatilised, and that in a sun-spot we have a local upheaval of this high temperature which volatilises the solid particles of carbon and enables us to see below the photospheric clouds? A spot being then a gaseous layer, it would part with

* A fluted spectrum was generally considered a very low-temperature one, but Hale's observation shows that carbon gives such a spectrum at a temperature of at least 7000° C., or twice the temperature of the arc.

nuch slower than the photosphere, and thus have its life
d.

ıs been urged that, even if the solar temperature was
ough to volatilise the photospheric clouds, they would
eform again at a greater altitude where the temperature
r ; but it is easy to see that the carbon vapour could not
ufficient altitude to reform into a cloud layer. If this
e would have cloud layers formed at suitable altitudes of
nium, magnesium, and many others ; and the fact that
not exist is, I think, a proof that carbon also, with a
rise of temperature, would be unable to remain in the
n.

erefore seems that brilliancy *per se* is no criterion as to
erature of a star, and if the solar temperature was raised
amount his brilliancy would fall probably 50 per cent.,
trum would show a considerable number of the lines of
magnesium, and others as bright lines, while the lines of
es like titanium and vanadium, which lie below the
ere, and the bands of carbon would be darkened and
. In fact, the solar spectrum would become almost
to that of IV. type stars, which should therefore be
s hotter and not cooler than the Sun.

gases that gives us the flash, and it evidently cannot rise much above the photosphere. In a sun-spot then the causes which give rise to the widening and darkening of some of the lines is partially due to the want of brilliancy of the gaseous layer below, and also to the greater depth of the absorbing vapours of the elements like titanium, &c., whose atomic weight gives them a place between the photosphere and the gaseous layer. The photospheric clouds seem to be not thick enough to be quite opaque, and a certain amount of light breaks through by the pores from the gaseous layer below. This helps to make the Fraunhofer lines darker than they would be if the photosphere was quite opaque to light coming from below. If the photosphere was of sufficient depth to be quite opaque, and also if the vapours of the elements lying below it could not reach the surface by convection currents, then only elements like hydrogen with a lighter atomic weight than twelve of carbon could lie above it, and we would get a spectrum like that of *Sirius*. As there would be only a few dark lines of hydrogen to absorb the light of the continuous spectrum the brilliancy of the star would be greatly enhanced principally in the violet end. This would not suggest, as Sir N. Lockyer urges, a higher temperature than the Sun, but one slightly cooler and not so near the critical temperature at which carbon can exist in the solid form.

Langenbach has shown that in a bright line spectrum as the temperature rises the maximum intensity shifts towards the violet end. Campbell finds that the Wolf-Rayet star D.M. + 30°3639 has an extensive hydrogen atmosphere, and that Hα is very faint, while Hγ is brighter, and Hβ very much brighter. This seems an interesting point in favour of the very high temperature of this class of stars.

As a summary of this paper I maintain that in the Sun, and also in stars of the same or lower temperature, we have two distinct layers which give us a continuous spectrum. First, a gaseous one of high temperature and pressure; and secondly, a layer of carbon clouds which are a far greater radiator than the first gaseous layer. In sun-spots where the temperature is locally high enough to volatilise the carbon clouds we get radiation from the gaseous layer alone and the absorption spectrum much intensified by those vapours which lie between these two layers. In stars like *Sirius* we get the spectrum due to a much greater depth of carbon clouds than we have in the Sun, and outside of which we have principally a great atmosphere of hydrogen. In IV. type and Wolf-Rayet stars we have bodies at too high a temperature for carbon clouds to form, and we have the continuous spectrum only from the gaseous layer, which is darkened also by the powerful absorption spectrum of carbon, titanium, and other elements with which the stars' atmosphere is charged.

The Spiral Nebula ♅ I. 153 *Ceti.* By W. S. Franks.

In revising the last working list at Starfield several objects were included that had previously been omitted on account of their great southern declination. The nebula ♅ I. 153 was one of these; so, taking advantage of an exceptionally clear sky on the evening of 1905 January 1 (when *Sirius* could be seen close to the horizon), I thought it was a favourable opportunity for attacking an object so long neglected. Although one of ♅'s Class I., it should, from its actinic effect, be relegated to Class II., for it is very faint on the original negative, and necessitated a repeated copy to bring it up to printing density (Plate 8).

Coming now to details, the object is N.G.C. 908, G.C. 536, ♅ I. 153, R.A. 2^h 18^m 28^s, Decl. $-21°$ $41'{\cdot}3$ (1900). It is described in the N.G.C. as "considerably bright, very large, extended." The photograph was obtained on 1905 January 1, with 90^m exposure in the 20-inch reflector, between 2^h 7^m and 3^h 37^m local sidereal time; very clear and severe frost. The photograph at once shows it to be a rather interesting left-handed spiral, viewed somewhat obliquely. It is about 4′ long by about $1\frac{1}{2}'$ broad, and its major axis lies at about pos. ang. $80° \pm$. There is a central condensation, and a detached small star about 3′ *following* the nucleus; also a brighter star about 10′ *following*. A peculiar feature is the bifurcation of the *following* arm of spiral. I do not remember a parallel case in an object of this kind. The already long list of spiral nebulæ gains yet another accession by the inclusion of this object. The accompanying illustration will assist the foregoing description. The scale is approximately 12″ of arc to 1 millimetre.

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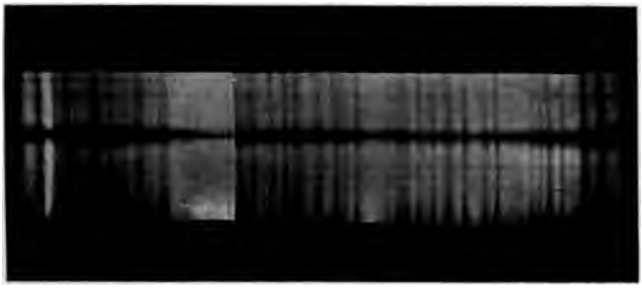
Further Note on the Origin of Magnitude-Equation in Photographic Measures. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

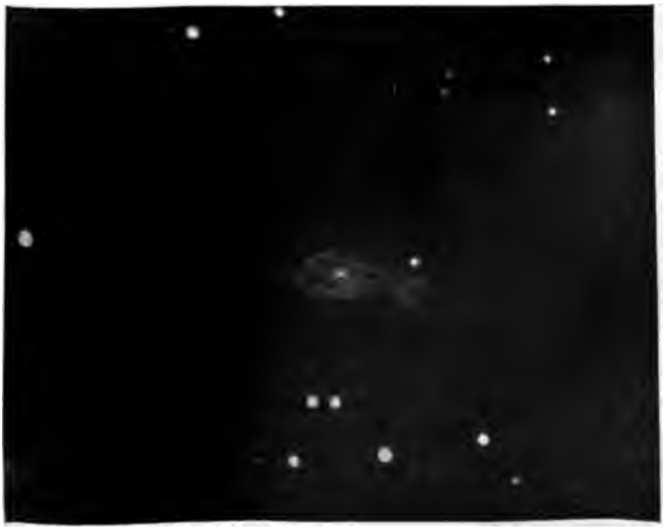
1. In *Monthly Notices*, vol. lxv. p. 54, I drew attention to the fact that a faulty objective may produce images showing a magnitude-equation which has not hitherto, so far as I know, been considered; and further reflection and discussion have not altered my opinion that such a possibility must always be taken into account in discussing photographic measures for very small quantities, as in parallax work. But a recent conversation with the Astronomer-Royal suggests that the precise form of fault in the objective was probably not correctly assigned; and it may

(DR. W. E. WILSON'S PAPER.)



SPECTRUM OF ARTIFICIAL SUN-SPOT.

(MR. W. S. FRANKS' PAPER.)



SPIRAL NEBULA H I. 153 CETI

Photographed by W. S. FRANKS.

be useful to others to know beforehand what to look for if there is so conspicuous an effect as to suggest mechanical correction.

2. The remark of the Astronomer-Royal is briefly to the effect that an error of *centring* of one lens, *i.e.* a lateral displacement of one lens relatively to the other, is not so likely to produce serious effects as a relative *tilt*. This he found by personal experience when adjusting the 28-inch objective at the Royal Observatory. There was originally a defect which gave unsymmetrical out-of-focus images, and he in the first instance attributed it to defective centring as above, but found on trial that one lens could be moved laterally with reference to the other by quantities of the order of a quarter of an inch without serious change of the images. He then tried relative tilt, and found that a very small correction of that kind gave the required results. Hence it seems more likely that we should look for defects in this direction, especially if the lenses of an objective are sensibly separated.

3. The defect in the Algiers objective, which gave rise to the well-marked magnitude-equation, was apparently of this kind, though arising in rather a different way. I gather from M. Trépied that a representative from M. Gautier found the lenses of the objective pressed too tightly together. Such pressure would be very unlikely to be quite symmetrical, and the effect might be regarded as a form of tilt.

4. With heavy objectives it seems desirable to be on the watch for an error of this kind depending on the pressure produced by the weight of the objective itself. Such errors would, it is to be hoped, be very small; but they might come within the scope of very refined investigations; and they might unfortunately become serious from the enormous labour required to investigate them. They would, in each individual plate, be associated with "driving error," or correction-of-refraction error which might be of the same kind; and could only be determined from the mean of a large number of plates.

On the Possible Effects of Radiation on the Motion of Comets, with special reference to Encke's Comet. By H. C. Plummer, M.A.

1. It may be said with confidence that the theory of radiation, which occupies a prominent place in modern physics, possesses an importance in astronomy which is only beginning to be appreciated. It has been suggested that the repulsive force manifested in the tails of comets finds its simplest explanation in this theory, and quite recently Arrhenius has appealed to the properties of radiation in a discussion of the physical nature of the solar corona. To Professor Poynting we are indebted for a memoir on

ion in the Solar System " (published in the *Philosophical* *tions* and reprinted in the *Memoirs* of this Society), which a lucid exposition of those details of the subject which oncern the astronomer. The discussion of the effects of n pressure, which is contained in the second part of his ggests many points of great astronomical interest, and l lead us to reconsider some of the conclusions hitherto Naturally it is in the sphere of meteoric astronomy that ence is mainly to be expected. To take an example, two l meteors of density 6·2 and radius 1 cm., possessing the ture which they acquire at the same distance from the ne Earth, neither attract nor repel one another, the gravi- stress being balanced by the radiation pressure. Facts his may well lead to a revision of the views at present held stability of meteor swarms, the subject of a series of well- esearches by Schiaparelli, Charlier, L. Picart and Callan- As Poynting suggests, such facts may have a bearing on ry of Saturn's rings provided the temperature of the s sufficiently high. Most significant of all, from the al point of view, is the modification, though not of course uction in the physical sense, of the law of action and It seems just conceivable that the transformation of

ance is made for the effect of radiation pressure the law is modified so that its expression becomes

$$n^2a^3 = \mu - \mu'$$

The change implies a virtual reduction in the Sun's mass. If μ'/μ is one-millionth and ρ is taken to be about 5·5, the corresponding value of a is about 13 cm. If the size of the constituent meteors reaches or exceeds this limit it is scarcely likely, with the present degree of accuracy in comet observations, that the departure from Kepler's law can be detected. But the meteors may very easily be considerably less than 10 inches in diameter, and in that case it should be possible to find evidence of the action of radiation pressure.

3. There is no difficulty in finding discrepancies between theory and observation in the orbital motions of comets, and the important question which confronts us is this: How far can such discrepancies be explained by the fact that an incorrect value may have been assumed of the effective mass of the Sun? The intention here is simply to suggest this question, not to give any definite answer to it. The case which has received the greatest amount of study is that of Encke's comet. The elements calculated for one apparition and corrected for the perturbations caused by known sources of disturbance during the interval in which the comet is beyond the range of observation are not satisfied by the observations made at the following apparition. To meet the difficulty it has been usual, from the time of Encke, to assign an empirical variation to the mean motion. This is explained by the hypothesis of a resisting medium for which there is no confirmatory evidence, and which seems to have been introduced simply *ad hoc*. Moreover, since the variation of the mean motion has not remained constant in all revolutions of the comet, it has been necessary to attribute properties to the medium which seem rather artificial. However this may be, the relation connecting the mean distance and the mean motion (thus varied) with what may be called the planetary mass of the Sun has presumably been preserved. If this assumption has in fact been made it is an important question how far the discrepancies between theory and observation can be explained by making allowance for the pressure due to solar radiation. Possibly a negative answer is implicitly contained in those works to which Dr. Backlund has devoted so much skill and labour. But if not, an interesting though laborious research is suggested, which has not yet been undertaken. The point here insisted on is that in the case of all comets it is unwarrantable to *assume* that the mean motion and the mean distance are related and not independent elements.

4. It has been supposed in what precedes that the size of the particles of which a comet is composed is uniform and permanent. This may not be the case. Collisions may cause them to coalesce,

o increase progressively in size. The radiation pressure s be diminished and an acceleration of the mean motion ult from this cause. At the same time there will be a nding diminution in the brightness of the comet. It is een, in fact, that if m spherical particles coalesce into rs both the radiation pressure, expressed in terms of the nding gravitative pull, and the brightness of the comet ged in the same ratio—namely, the cube root of $m : n$. uses may be imagined for an alteration, either continuous ntinuous, in the size of the meteors. Hence, even if e is supposed originally uniform, it will not necessarily o. The pressure due to solar radiation may thus through tive action become a powerful factor in the disintegration s. Is it possible that we have here an explanation of the us behaviour of Biela's comet? If from any cause or tion of causes the constituent particles became separated distinct sizes, the division of the nucleus follows as a consequence. The idea that the dimensions of the constituents were wanting in stability is supported by rkable variations in the relative brightness of the two d by the ultimate disappearance of the comet, which may n due either to its transformation into a meteor swarm

years. This may be otherwise expressed by saying that its period of revolution is diminished by 0·2 sec. a year. If the same laws were applicable to a body actually as large as the Earth, the result would be to diminish the length of the year by 1 second in 3×10^9 years. The concrete question suggested by such results is whether the effect can reach an order which will account for the anomalous features which have been observed in the motion of Encke's comet.

6. Since T is constant for all distances and of an order such that its first power alone need be retained, the perturbations of an elliptic orbit, being entirely in the plane of motion, can be calculated very simply. The equations of motion can be written

$$\ddot{r} - r\dot{\theta}^2 = -\frac{\mu-\mu'}{r^2} - \frac{T}{r^2}\dot{r}$$

$$\frac{d}{dt}(r^2\dot{\theta}) = -T\frac{d\theta}{dt}$$

Integrating the latter and then eliminating t from the former, we get

$$r^2\dot{\theta} = T/c - T\theta$$

$$\frac{d^2u}{d\theta^2} + u = \frac{(\mu-\mu')c^2}{T^2(1-c\theta)^2}$$

where u is the reciprocal of r, and c is an integration constant of the same order of magnitude as T. Hence the last equation may be replaced by the approximate form

$$\frac{d^2u}{d\theta^2} + u = (\mu-\mu')\ (1+2c\theta)c^2/T^2$$

of which the integral is

$$u = (\mu-\mu')\ [1 + e\cos(\theta-\gamma) + 2c\theta]c^2/T^2$$

Now it is evident, on general grounds, that the departure from a purely elliptic orbit in any one revolution is small. The preceding equation may therefore be considered a valid representation, during a small number of revolutions, of the motion of a particle which would, in the absence of the effect now considered, describe the elliptic orbit

$$u = (\mu-\mu')\ [1 + e\cos(\theta-\gamma)]c^2/T^2$$

7. For the sake of definiteness and simplicity we may consider the motion at successive returns to the position which corresponds to the perihelion in the undisturbed orbit and put $\gamma = 0$. After k returns the motion is given by

$$u = (\mu-\mu')\ [1 + e\cos\theta + 2c(2\pi k + \theta)]c^2/T^2$$

ncreases from the value o. The osculating orbit at the
= o is therefore

$$u = (\mu - \mu') \left[1 + e \cos\theta + 2c(2\pi k + \sin\theta)\right] c^2/T^2$$

s an ellipse with its focus at the Sun and possessing the
le of curvature as the disturbed orbit; and since the
g force has no normal component, equality of curvature
quality of velocity in this ellipse and in the actual orbit.
the equation in a form in which the meaning of the
s is obvious, namely

$$lu = 1 + e' \cos(\theta - \beta)$$

$$l^{-1} = (\mu - \mu')(1 + 4\pi ck)c^2/T^2$$

n $\beta = 2c/e$

$e'/l = (\mu - \mu')(e^2 + 4c^2)^{\frac{1}{2}} c^2/T^2$

e the increments of the constants at each revolution.
ion of the apse-line is constant and the variations of l
f which the accent becomes superfluous) are given by

Now

$$I_2 = \pi(1-e^2)^{-\frac{3}{2}}.$$
$$I_3 = \tfrac{1}{2}\pi(2+e^2)(1-e^2)^{-\frac{5}{2}}$$

Hence

$$P = \frac{2\pi T^3}{c^3(\mu-\mu')^2}(1-e^2)^{-\frac{3}{2}}\left\{1-3\pi c(2k+1)\frac{1+e^2}{1-e^2}\right\}$$

This is the period in the $(k+1)$th revolution, and consequently the variation of the period is given by

$$\frac{\delta P}{P} = -6\pi c\frac{1+e^2}{1-e^2}$$

which verifies the result found for the mean motion.

9. Now T/c is twice the areal velocity; hence if q is the perihelion distance

$$T/c = q^2 n(1+e)^{\frac{1}{2}}(1-e)^{-\frac{3}{2}}$$

Therefore

$$\delta n = 6\pi T(1+e^2)(1+e)^{-\frac{3}{2}}(1-e)^{\frac{1}{2}}/q^2$$

Using $1{\cdot}75\times10^6$ as the value of S and 3×10^{10} as the value of U in the expression given for T (§ 5), we have

$$6\pi T = 9{\cdot}2\times10^{-15}b^2/\rho a$$

Hence

$$\delta n = 9{\cdot}2\times10^{-15}(1+e^2)(1+e)^{-\frac{3}{2}}(1-e)^{\frac{1}{2}}b^2/q^2\rho a$$

or

$$\rho a = 9{\cdot}2\times10^{-15}\frac{(1+e^2)(1-e)^{\frac{1}{2}}}{(1+e)^{\frac{3}{2}}}\cdot\frac{b^2}{q^2}\cdot\frac{1}{\delta n} \quad \ldots \quad \ldots \quad (1)$$

which is the formula (in C.G.S. units), giving ρa when δn is known. Moreover, by connecting the expressions for δe and δn in terms of c (§ 7), we have

$$\frac{\delta e}{e} = -\frac{2}{3}\cdot\frac{1-e^2}{1+e^2}\cdot\frac{\delta n}{n}$$

or putting $\quad e = \sin\phi$

$$\delta\phi = -\frac{1}{3}\cdot\frac{\sin 2\phi}{1+\sin^2\phi}\cdot\frac{\delta n}{n} \quad \ldots \quad \ldots \quad (2)$$

10. To represent the conditions of Encke's comet it is sufficient to take $q = \frac{1}{3}b$, $e = 0{\cdot}85$, $\phi = 58°$, and $n = 1070''$ per day. In accordance with Backlund's results, derived from the more recent apparitions, we may take $0''{\cdot}068$ as the increment of the mean daily motion in a revolution. The result of substituting these numbers in (2) is to give $\delta\phi = -2''{\cdot}3$, while Backlund's corresponding result is $-2''{\cdot}4$. The agreement between the two

is, however, only apparently remarkable, for its signifi-
scarcely greater than that of an arithmetical check. As
l has pointed out, the relation between the variations δn
vhich arise from the action of a resisting medium is
ly independent of the nature of the medium, and can be
to be known. Hence, the action of the disturbing
re considered being formally identical with that of a
medium of simple type, it follows that the agreement is
nothing more than ought to be expected.

3y expressing the above value of δn with a second as the
ime and reducing to circular measure, we obtain

$$\delta n = 1/2{\cdot}62 \times 10^{11}$$

ie formula (1) gives

$$\begin{aligned} \rho a &= 9{\cdot}2 \times 10^{-15} \times 0{\cdot}265 \times 9 \times 2{\cdot}62 \times 10^{11} \\ &= 5{\cdot}7 \times 10^{-3} \end{aligned}$$

shows that if we assume the density to be about equal
nean density of the Earth a particle whose radius is
lredth of a millimetre and whose orbit round the Sun is

the theory of radiation must apparently be regarded as an interesting but untenable speculation.

12. This, however, is not a conclusion from which there is definitely no escape. We are not so much seeking for a cause of the known peculiarity of the motion of Encke's comet as looking to that peculiarity for evidence of an actual physical process. Hence it seems unwise to dismiss hastily a theory in some ways so attractive. It may be possible, for instance, that the diminution in the solar attraction is neutralised by some other action such as electrostatic attraction. And apart from this possibility there is a consideration of a different kind. We have assumed a meteoric constitution for the comet, and it is difficult to avoid some such theory because the notion that a comet is composed of continuous matter seems impossible. Being widely dispersed the meteors must be practically unaffected by their mutual attractions, and may be considered to describe independent orbits. It is to *each member* of the total aggregate of orbits that the foregoing investigation applies, while the observations and the elements based on them refer to an object resulting indeed from the same aggregate, but connected with the individual members in a vague and undefined manner. Since we cannot observe each distinct meteor and trace its relative path within the swarm it is not necessary to assume that the mean distance which is deduced from the observations, and which has a significance purely statistical and quite possibly misleading, is identical with the mean distance of any particular meteor or the true average of the total number. This distinction, for which the theory of waves presents some analogy in the difference between group-velocity and wave-velocity, may be illustrated by the simplest possible example: if two particles describe similar coplanar orbits differing only in the fact that their axes are inclined to one another at an angle 2ϵ, the point midway between them also describes a similar orbit, but with a mean distance which bears to the mean distance of each particle the ratio $\cos\epsilon : 1$. The difficulty of assigning a definite dynamical meaning to the point to which the observations refer is further emphasised by the systematic differences which have been found to exist between observations made with large and with small telescopes. The great obstacle in the way of a satisfactory study of the statistical conditions lies in the difficulty of formulating an appropriate hypothesis regarding the complex motions of the constituents of the swarm.

University Observatory, Oxford:
1905 *January* 11.

'alidity of Meteor Radiants deduced from Three Tracks.

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(*Communicated by L. N. G. Filon, M.A., D.Sc.*)

is not uncommon in tables of radiants of meteors to ants deduced from very few observations: four is quite n number, and three by no means rare. We see, how- t it is quite possible that three or four paths, although onnected, should happen to pass so closely through the nt that they would be taken to indicate a radiant there. ore becomes of interest to determine the probability of pening. Suppose the mean divergence of an observed n the radiant is ω, then it is clear that if the inradius formed by the paths of three meteors $\ngtr \omega$ the three ll be considered to pass through the same point and, certain conditions which will be investigated later, to a radiant there.

problem before us is, therefore, to find the chance that cle of the Δ formed by three great circles taken at n a sphere $\ngtr \omega$.

The chance of AB falling between x and $x+dx$

$$=\frac{2\pi \sin x dx}{2\pi} \sin x dx.$$

Then if $x<2\omega$ any ⊙ through A and B′, the point antipodal to B has a radius $>\frac{1}{2}\pi-\omega$, and the conditions are certainly satisfied. If $x>2\omega$, let A′ be the point antipodal to A, and through A, B; A, B′; A′, B; and A′, B′ draw circles of radius $\frac{1}{2}\pi-\omega$. We will for the present only consider the four of the eight circles whose major arcs lie on one of the two hemispheres into which the sphere is divided by the plane ABA′B′.

3. We will now find the condition that the circles through A, B; A′, B′ may cut each other. Let P be the centre of the ⊙ through AB, and draw PX perp. to AB. Then

$$\cos PX = \cos AP \sec AX = \sin \omega \sec \tfrac{1}{2}x,$$

and we see that the circles will cut if

$$2\{PX+(\tfrac{1}{2}\pi-\omega)\}>\pi,$$

i.e. $$PX>\omega,$$

i.e. $$\sin\omega \sec \tfrac{1}{2}x<\cos\omega,$$

i.e. $$\cos \tfrac{1}{2}x>\tan\omega.$$

Since $x<\frac{\pi}{2}$, this is always true if $\omega<\tan^{-1}\frac{1}{\sqrt{2}}$, which is the case, ω being small.

∴ the circles through A, B; A′, B′ will cut; let them cut in D, E (fig. 2).

Similarly the circles through A, B′; A′, B will cut if

$$\sin\frac{x}{2}>\tan\omega,$$

i.e. $$x>2\sin^{-1}\tan\omega.$$

Now it will be seen that the conditions will not be satisfied if C, the pole of the third circle which lies in the hemisphere considered, fall within all four of the circles through A, B; A, B′; A′, B; A′, B′, but will in every other case.

The conditions will be satisfied if C falls within both of the circles through any one of our four pairs of points; but this gives nothing new, for the second circle through AB is antipodal to A′B′D and so can have no points in common with it, so that our conditions are already satisfied by C being outside A′B′D, and similarly for the other pairs of points.

Now if the circles through A′, B; A, B′ do not cut, the four

ill have no common portion and the conditions will be
Now these circles will not cut unless $x > 2\sin^{-1}\tan\omega$,

$$\text{ance in this way} = \int_0^{2\sin^{-1}\tan\omega} \sin x\, dx$$

$$= 1 - \cos 2(\sin^{-1}\tan\omega)$$

$$= 2\tan^2\omega \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

nsider now the case when the circles through A, B′;
in F, G.
we have two subcases, according as the points F, G lie
de or both outside of the area common to ABD, A′B′D.
F, G will clearly lie on the same great ⊙.
F and G will both lie inside the area common to ABD,

$$\text{FG} < 2\{\tfrac{1}{2}(\pi - \omega + \text{PX}) - \tfrac{1}{2}\pi\}$$

$$< 2(\text{PX} - \omega).$$

d FG, let Q be the centre of A′BG and draw QY perp.
Then $\cos\frac{1}{2}\text{FG} = \cos\text{QF}\sec\text{QY}$.
Y cut AB A′B′ in Z.

But this will not satisfy our equation ; it satisfies

$$\tfrac{1}{8}\{8-5\cos^2\omega-\cos\omega\,(25\cos^2\omega-16)^{\frac{1}{2}}\}=\tfrac{1}{2}.$$

So $\frac{1}{8}\{8-5\cos^2\omega+\cos\omega\,(25\cos^2\omega-16)^{\frac{1}{2}}\}$ never $=\frac{1}{2}$, and it is sometimes greater, so it is always greater, since it is continuous.

So the second condition is never fulfilled.

The other condition is

$$x<2\sin^{-1}\tfrac{1}{8}\{8-5\cos^2\omega-\cos\omega\,(25\cos^2\omega-16)^{\frac{1}{2}}\}^{\frac{1}{2}}<\theta \quad \ldots \quad (2)$$

This assumes $25\cos^2\omega-16 \nless 0$,

$\therefore$ $\cos\omega \nless \frac{4}{5}$,

i.e. $\omega<36^\circ$ about, which will be true.

For this subcase to actually occur we must have

$$\theta>2\sin^{-1}\tan\omega.$$

We can see that this will always happen by considering fig. 1, for what we assert is that there are always real positions of F and G inside the figure DE ; and we can see that this is true, for ABD, A′B′D always cut, so that DE always exists, and is of finite size, even when F and G coincide in Y, so that F and G are inside the figure DE in this case, and cannot get outside it until FG has attained a certain finite size.

5. We will now consider the subcase when $2\sin^{-1}\tan\omega<x<\theta$ and F and G lie inside DE, fig. 1. Then the conditions will be fulfilled if C lies outside the figure FG, the chance of which is

$$\frac{2\pi-\text{area FG}}{2\pi}.$$

$$\begin{aligned}\text{And area FG} &= 2(\text{sector FQG}-\Delta\text{FQG})\\ &= 2\{(1-\sin\omega)\text{F}\hat{\text{Q}}\text{G}+(\pi-\text{F}\hat{\text{Q}}\text{G}-2\text{F}\hat{\text{G}}\text{Q})\}\\ &= 2\pi-2\sin\omega\,\text{F}\hat{\text{Q}}\text{G}-4\text{F}\hat{\text{G}}\text{Q}\,;\end{aligned}$$

$\therefore$ chance of conditions being fulfilled $=\pi^{-1}(\sin\omega\,\text{F}\hat{\text{Q}}\text{G}+2\text{F}\hat{\text{G}}\text{Q})$.

$$\begin{aligned}\text{F}\hat{\text{Q}}\text{G} &= 2\text{Y}\hat{\text{Q}}\text{F}\\ &= 2\cos^{-1}(\tan\text{QY}\cot\text{QF})\\ &= 2\cos^{-1}\{\tan\omega\cot\cos^{-1}(\sin\omega\,\text{cosec}\,\tfrac{1}{2}x)\}\\ &= 2\cos^{-1}\left\{\sin\omega\tan\omega\left(\sin^2\frac{x}{2}-\sin^2\omega\right)^{-\frac{1}{2}}\right\}\end{aligned}$$

$$\begin{aligned}\text{and} \qquad \text{F}\hat{\text{G}}\text{Q} &= \sin^{-1}(\sin\text{QY}\,\text{cosec}\,\text{QF})\\ &= \sin^{-1}\left(\tan\omega\,\text{cosec}\,\frac{x}{2}\right);\end{aligned}$$

$\therefore$ chance of conditions being fulfilled

$$=2\pi^{-1}\left[\sin\omega\cos^{-1}\left\{\sin\omega\tan\omega\left(\sin^2\frac{x}{2}-\sin^2\omega\right)^{-\frac{1}{2}}\right\}+\sin^{-1}\left(\tan\omega\,\text{cosec}\,\frac{x}{2}\right)\right];$$

e total chance of conditions being fulfilled under this

$$= \int_{2\sin^{-1}\tan\omega}^{\theta} 2\pi^{-1} \left[\sin\omega \cos^{-1}\left\{ \sin\omega \tan\omega \left(\sin^2\frac{x}{2} - \sin^2\omega \right)^{-\frac{1}{2}} \right\} + \sin^{-1}\left(\tan\omega \operatorname{cosec}\frac{x}{2} \right) \right] \sin x \, dx.$$

$$\int \cos^{-1}\{\sin\omega \tan\omega (\sin^2 \tfrac{1}{2}x - \sin^2\omega)^{-\frac{1}{2}}\} \sin x \, dx$$

$$x \cos^{-1}\{\sin\omega \tan\omega \, (\sin^2 \tfrac{1}{2}x - \sin^2 \omega^{-\frac{1}{2}}\}$$

$$n\,\omega \tan\omega \int \cos x \sin \tfrac{1}{2}x \cos \tfrac{1}{2}x \, (\sin^2 \tfrac{1}{2}x - \sin^2 \omega)^{-1} (\sin^2 \tfrac{1}{2}x - \tan^2 \omega)^{-\frac{1}{2}} \, dx$$

$$x \cos^{-1}\{\sin\omega \tan\omega \, (\sin^2 \tfrac{1}{2}x - \sin^2 \omega)^{-\frac{1}{2}}\}$$

$$\sin\omega \tan\omega \int \sin x \cos x \, (\cos 2\omega - \cos x)^{-1} (1 - 2\tan^2\omega - \cos x)^{-\frac{1}{2}} \, dx$$

$$x \cos x \, (\cos 2\omega - \cos x)^{-1} (1 - 2\tan^2\omega - \cos x)^{-\frac{1}{2}} \, dx$$

and

$$\int \sin^{-1}(\tan\omega \operatorname{cosec}\tfrac{1}{2}x)\sin x\,dx = -\cos x\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}x)$$
$$-\int \tfrac{1}{2}\tan\omega\cos x\cos\tfrac{1}{2}x\operatorname{cosec}^2\tfrac{1}{2}x\,(1-\tan^2\omega\operatorname{cosec}^2\tfrac{1}{2}x)^{-\frac{1}{2}}\,dx$$

$$\int \tfrac{1}{2}\tan\omega\cos x\cos\tfrac{1}{2}x\operatorname{cosec}^2\tfrac{1}{2}x\,(1-\tan^2\omega\operatorname{cosec}^2\tfrac{1}{2}x)^{-\frac{1}{2}}\,dx$$
$$=\int \tan\omega\,(\tfrac{1}{2}\cos\tfrac{1}{2}x\operatorname{cosec}^2\tfrac{1}{2}x-\cos\tfrac{1}{2}x)(1-\tan^2\omega\operatorname{cosec}^2\tfrac{1}{2}x)^{-\frac{1}{2}}\,dx$$
$$=-\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}x)-\int\sin\tfrac{1}{2}x\cos\tfrac{1}{2}x\tan\omega\,(\sin^2\tfrac{1}{2}x-\tan^2\omega)^{-\frac{1}{2}}\,dx$$
$$=-\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}x)-2\tan\omega\,(\sin^2\tfrac{1}{2}x-\tan^2\omega)^{\frac{1}{2}};$$
$$\therefore \int\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}x)\sin x\,dx = 2\sin^2\tfrac{1}{2}x\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}x)+2\tan\omega\,(\sin^2\tfrac{1}{2}x-\tan^2\omega)^{\frac{1}{2}};$$
$$\therefore \int_{2\sin^{-1}\tan\omega}^{\theta} 2\pi^{-1}\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}x)\sin x\,dx = 4\pi^{-1}\sin^2\tfrac{1}{2}\theta\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}\theta)$$
$$+4\pi^{-1}\tan\omega\left(\sin^2\frac{\theta}{2}-\tan^2\omega\right)^{\frac{1}{2}}-2\tan^2\omega;$$

∴ total chance under this subcase is

$$2\pi^{-1}\sin\omega\,[\cos 2\omega\tan^{-1}\{2^{-\frac{1}{2}}\operatorname{cosec}\omega\cot\omega\,(1-2\tan^2\omega-\cos\theta)^{\frac{1}{2}}\}$$
$$-\cos\theta\cos^{-1}\{\sin\omega\tan\omega\,(\sin^2\tfrac{1}{2}\theta-\sin^2\omega)^{-\frac{1}{2}}\}$$
$$-\sin\omega\tan\omega\,2^{\frac{1}{2}}(1-2\tan^2\omega-\cos\theta)^{\frac{1}{2}}]+4\pi^{-1}\sin^2\tfrac{1}{2}\theta\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}\theta)$$
$$+4\pi^{-1}\tan\omega\,(\sin^2\tfrac{1}{2}\theta-\tan^2\omega)^{\frac{1}{2}}-2\tan^2\omega \quad . \;.\;.\;.\;.\;.\;.\;. \quad (3)$$

6. If F and G lie outside the area common to ABD, A′B′D, (fig. 2), let ABD cut AFB′ in H and A′FB in K, and let A′B′D cut AFB′ in L and A′FB in M. Then the conditions will be satisfied if C falls outside HKML, and then only.

Now AKHB + B′HLA + B′MLA′ + A′KMB

$$\begin{aligned}
&= \text{AFB} + \text{AFMD} + \text{MDK} + \text{FML} + \text{BFLE} + \text{LEH} + \text{HKML}\\
&+ \text{ADB}' + \text{DKGB}' + \text{HKG} + \text{MDK} + \text{AFMD} + \text{FML} + \text{HKML}\\
&+ \text{A}'\text{GB}' + \text{GHEA}' + \text{LEH} + \text{HKG} + \text{B}'\text{DKG} + \text{MDK} + \text{HKML}\\
&+ \text{A}'\text{EB} + \text{FLEB} + \text{FML} + \text{LEH} + \text{A}'\text{GHE} + \text{GHK} + \text{HKML}\\
&= 2\pi + \text{FML} + \text{BFLE} + \text{LEH} + \text{HKML}\\
&\quad + \text{MDK} + \text{AFMD} + \text{FML} + \text{HKML}\\
&\quad + \text{HKG} + \text{B}'\text{DKG} + \text{MDK} + \text{HKML}\\
&\quad + \text{LEH} + \text{A}'\text{GHE} + \text{GHK} + \text{HKML} - \text{HKML}\\
&= 2\pi + 4\text{BFKE} - \text{HKML};
\end{aligned}$$

$$\therefore \text{HKML} = 2\pi + 4\text{BFKE} - 2\text{AKHB} + 2\text{AHB}';$$

of conditions being fulfilled

$$= \frac{2\pi - \text{HKML}}{2\pi} = \pi^{-1}(\text{AKHB} + \text{AFHB}' - 2\text{BFKE}).$$

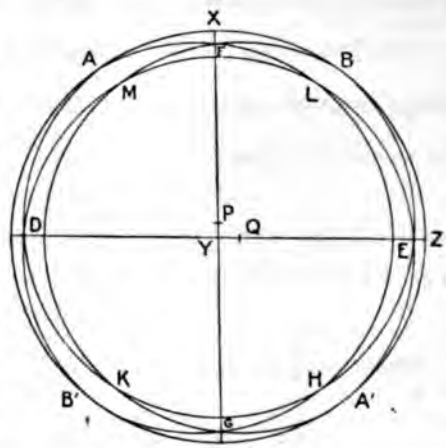


Fig. 2.

Also

$$\text{AKHB} = \text{sector PAKHB} + \Delta\text{APB}$$
$$= (1 - \sin\omega)(2\pi - 2x\hat{\text{P}}\text{B}) + 2x\hat{\text{P}}\text{B} + 2\text{A}\hat{\text{B}}\text{P} - \pi$$
$$= \pi(1 - 2\sin\omega) + 2\sin\omega\sin^{-1}(\sin\tfrac{1}{2}x\sec\omega)$$
$$+ 2\cos^{1}(\tan\tfrac{1}{2}x\tan\omega)$$

Similarly

$$\text{AFHB}' = \pi(1 - 2\sin\omega) + 2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega)$$
$$+ 2\cos^{-1}(\cot\tfrac{1}{2}x\tan\omega)\,;$$

$$\therefore \quad \text{AKHB} + \text{AFAB}' - 2\text{BFKE}$$
$$= -2\pi(1 + 2\sin\omega) + 2\sin\omega\sin^{-1}(\sin\tfrac{1}{2}x\sec\omega)$$
$$+ 2\cos^{-1}(\tan\tfrac{1}{2}x\tan\omega) + 2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega)$$
$$+ 2\cos^{-1}(\cot\tfrac{1}{2}x\tan\omega)$$
$$+ 8\sin\omega\cot^{-1}[\sin\omega\tan\tfrac{1}{2}\{\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)$$
$$+ \sin^{-1}(\tan\tfrac{1}{2}x\tan\omega)\}]$$
$$= 2\sin\omega\sin^{-1}(\sin\tfrac{1}{2}x\sec\omega) + 2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega)$$
$$+ 2\sin^{-1}(\tan\tfrac{1}{2}x\tan\omega) + 2\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)$$
$$- 8\sin\omega\tan^{-1}[\sin\omega\tan\tfrac{1}{2}\{\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)$$
$$+ \sin^{-1}(\tan\tfrac{1}{2}x\tan\omega)\}]\,;$$

$\therefore$ total chance of conditions being fulfilled under this subcase

$$= 2\pi^{-1}\int_{0}^{\frac{\pi}{2}}\Big\{\sin\omega\sin^{-1}(\sin\tfrac{1}{2}x\sec\omega) + \sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega)$$
$$+ \sin^{-1}(\tan\tfrac{1}{2}x\tan\omega) + \sin^{-1}(\tan\tfrac{1}{2}x\tan\omega)$$
$$- 4\sin\omega\tan^{-1}[\sin\omega\tan\tfrac{1}{2}\{\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)$$
$$+ \sin^{-1}(\tan\tfrac{1}{2}x\tan\omega)\}]\Big\}\sin x\,dx \quad \ldots \quad (4)$$

8. $\int \sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)\sin x\,dx$

$$= -\cos x\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)$$
$$- \int \tfrac{1}{2}\cos x\tan\omega\operatorname{cosec}^2\tfrac{1}{2}x(1 - \cot^2\tfrac{1}{2}x\tan^2\omega)^{-\frac{1}{2}}dx$$
$$= -\cos x\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)$$
$$- \int \tfrac{1}{2}\tan\omega\cos x\operatorname{cosec}\tfrac{1}{2}x(\sin^2\tfrac{1}{2}x - \tan^2\omega\cos^2\tfrac{1}{2}x)^{-\frac{1}{2}}dx.$$

$$\int \tfrac{1}{2}\tan\omega\cos x\operatorname{cosec}\tfrac{1}{2}x(\sin^2\tfrac{1}{2}x - \tan^2\omega\cos^2\tfrac{1}{2}x)^{-\frac{1}{2}}dx$$
$$= \int \tfrac{1}{2}\tan\omega\operatorname{cosec}\tfrac{1}{2}x(1 - \sec^2\omega\cos^2\tfrac{1}{2}x)^{-\frac{1}{2}}dx$$
$$- \int \tan\omega\sin\tfrac{1}{2}x(1 - \sec^2\omega\cos^2\tfrac{1}{2}x)^{-\frac{1}{2}}dx$$
$$= \int \tfrac{1}{2}\tan\omega\operatorname{cosec}\tfrac{1}{2}x(1 - \sec^2\omega\cos^2\tfrac{1}{2}x)^{-\frac{1}{2}}dx$$
$$+ 2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega)$$
$$= 2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega) + \int \tan\omega(u^2 + \tan^2\omega)^{-1}du\,;$$

$$1-\cos^2\tfrac{1}{2}x\sec^2\tfrac{1}{2}\omega = u^2\cos^2\tfrac{1}{2}x$$

$$= 2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega)+\tan^{-1}(u\cot\omega)$$

$$= 2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega)+\tan^{-1}\{\cot\omega(\sec^2\tfrac{1}{2}x - \sec^2\omega)^{-\frac{1}{2}}\};$$

$$\text{n}^{-1}(\cot\tfrac{1}{2}x\tan\omega)\sin x\,dx$$

$$= -\cos x\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)-2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}x\sec\omega) - \tan^{-1}\{\cot\omega(\sec^2\tfrac{1}{2}x-\sec^2\omega)^{-\frac{1}{2}}\}$$

$$\text{sin}^{-1}(\tan\tfrac{1}{2}x\tan\omega)\sin x\,dx$$

$$= -\int_{\pi-\theta}^{\frac{\pi}{2}}\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)\sin x\,dx$$

$$\{\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)+\sin^{-1}(\tan\tfrac{1}{2}x\tan\omega)\}\sin x\,dx$$

$$\therefore \int_{\theta}^{\frac{\pi}{2}} \{\sin^{-1}(\sin \tfrac{1}{2}x \sec \omega) + \sin^{-1}(\cos \tfrac{1}{2}x \sec \omega)\} \sin x \, dx$$

$$= \cos \tfrac{1}{2}\theta(\cos^2 \omega - \cos^2 \tfrac{1}{2}\theta)^{\frac{1}{2}} - (\cos^2 \omega - 2 \cos^2 \tfrac{1}{2}\theta) \sin^{-1}(\cos \tfrac{1}{2}\theta \sec \omega) - \sin^2 \tfrac{1}{2}\theta(\cos^2 \omega - \sin^2 \tfrac{1}{2}\theta)^{\frac{1}{2}} + (\cos^2 \omega - 2 \sin^2 \tfrac{1}{2}\theta) \sin^{-1}(\sin \tfrac{1}{2}\theta \sec \omega) \quad \ldots \quad (6)$$

$$\tan \tfrac{1}{2}\{\sin^{-1}(\cot \tfrac{1}{2}x \tan \omega) + \sin^{-1}(\tan \tfrac{1}{2}x \tan \omega)\}$$

$$= \cot \tfrac{1}{2}\{\cos^{-1}(\cot \tfrac{1}{2}x \tan \omega) + \cos(\tan \tfrac{1}{2}x \tan \omega)\}$$

$$= \{1 - (1 - \tan \tfrac{1}{2}x \tan \omega)^{\frac{1}{2}}(1 + \tan \tfrac{1}{2}x \tan \omega)^{-\frac{1}{2}}(1 - \tan \omega \cot \tfrac{1}{2}x)^{\frac{1}{2}} (1 + \cot \tfrac{1}{2}x \tan \omega)^{-\frac{1}{2}}\} \{(1 - \tan \tfrac{1}{2}x \tan \omega)^{\frac{1}{2}} (1 + \tan \tfrac{1}{2}x \tan \omega)^{-\frac{1}{2}} + (1 - \cot \tfrac{1}{2}x \tan \omega)^{\frac{1}{2}} (1 + \cot \tfrac{1}{2}x \tan \omega)^{-\frac{1}{2}}\}^{-1}$$

$$= 2\{(1 - \tan \tfrac{1}{2}x \tan \omega)^{\frac{1}{2}}(1 + \tan \tfrac{1}{2}x \tan \omega)^{-\frac{1}{2}}(1 + \cot \tfrac{1}{2}x \tan \omega)^{-1} - (1 - \cot \tfrac{1}{2}x \tan \omega)^{\frac{1}{2}}(1 + \cot \tfrac{1}{2}x \tan \omega)^{-\frac{1}{2}}(1 - \tan \tfrac{1}{2}x \tan \omega)^{-1}\} \{(1 - \tan \tfrac{1}{2}x \tan \omega)(1 + \tan \tfrac{1}{2}x \tan \omega)^{-1} - (1 - \cot \tfrac{1}{2}x \tan \omega) (1 + \cot \tfrac{1}{2}x \tan \omega)^{-1}\}^{-1}$$

$$= \cot \omega \left(\cot \frac{x}{2} - \tan \frac{x}{2}\right)^{-1} \{(1 - \tan^2 \tfrac{1}{2}x \tan^2 \omega)^{\frac{1}{2}} - (1 - \cot^2 \tfrac{1}{2}x \tan^2 \omega)^{\frac{1}{2}}\}$$

$$= 2^{-\frac{1}{2}} \operatorname{cosec} \omega \sec x \left\{\sin \frac{x}{2} (\cos x + \cos^2 \omega)^{\frac{1}{2}} - \cos \frac{x}{2} (\cos 2\omega - \cos x)^{\frac{1}{2}}\right\};$$

$$\therefore \int \tan^{-1}[\sin \omega \tan \tfrac{1}{2}\{\sin^{-1}(\cot \tfrac{1}{2}x \tan \omega) + \sin^{-1}(\tan \tfrac{1}{2}x \tan \omega)\}] \sin x \, dx$$

$$= \int \tan^{-1}[2^{-\frac{1}{2}} \sec x \{\sin \tfrac{1}{2}x(\cos x + \cos 2\omega)^{\frac{1}{2}} - \cos \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}] \sin x \, dx$$

$$= -\cos x \tan^{-1}[2^{-\frac{1}{2}} \sec x \{\sin \tfrac{1}{2}x(\cos x + \cos 2\omega)^{\frac{1}{2}} - \cos \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}]$$

$$+ \int 2^{-\frac{1}{2}}[\sec x \{\tfrac{1}{2} \cos \tfrac{1}{2}x(\cos 2\omega + \cos x)^{\frac{1}{2}} - \tfrac{1}{2} \sin \tfrac{1}{2}x \sin x (\cos x + \cos 2\omega)^{-\frac{1}{2}} + \tfrac{1}{2} \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}} - \tfrac{1}{2} \cos \tfrac{1}{2}x \sin x (\cos 2\omega - \cos x)^{\frac{1}{2}}\} + \sin x \sec^2 x \{\sin \tfrac{1}{2}x(\cos 2\omega + \cos x) - \cos \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}][1 + \tfrac{1}{2} \sec^2 x \{\sin^2 \tfrac{1}{2}x (\cos x + \cos 2\omega) + \cos^2 \tfrac{1}{2}x(\cos 2\omega - \cos x) - \sin x (\cos^2 2\omega - \cos^2 x)^{\frac{1}{2}}]\cos x \, dx$$

The integral in this expression =

$$\int 2^{\frac{1}{2}} \cos x \{\cos \tfrac{1}{2}x(\cos 2\omega + \cos x)^{\frac{1}{2}} - \tfrac{1}{2} \cos x \cos \tfrac{1}{2}x(\cos 2\omega + \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x \cos x(\cos 2\omega - \cos x)^{\frac{1}{2}} - \tfrac{1}{2} \sin \tfrac{1}{2}x \sin x \cos x(\cos 2\omega + \cos x)^{-\frac{1}{2}} - \tfrac{1}{2} \cos \tfrac{1}{2}x \sin x \cos x (\cos 2\omega - \cos x)^{-\frac{1}{2}}\} \{\cos^2 x + \cos^2 2\omega - \sin x (\cos^2 2\omega - \cos^2 x)^{\frac{1}{2}}\}^{-1} dx$$

$$\{\cos \tfrac{1}{2}x(\cos 2\omega + \cos x)^{\frac{1}{2}} - \cos x \cos \tfrac{1}{2}x \cos^2 \omega$$

$$(\cos 2\omega + \cos x)^{-\frac{1}{2}} - \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)$$

$$- \cos x \sin \tfrac{1}{2}x \cos^2 \omega(\cos 2\,\omega - \cos x)^{-\frac{1}{2}}\}$$

$$\{\cos \tfrac{1}{2}x(\cos 2\omega + \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}^{-2}\, dx$$

$$\text{os}\, x\, \{\cos \tfrac{1}{2}x(\cos 2\,\omega + \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}^{-1}\, dx$$

$$\omega \int \{\cos \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}} + \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}$$

$$(\cos^2 2\omega - \cos^2 x)^{-\frac{1}{2}}\, \{\cos \tfrac{1}{2}x(\cos 2\omega + \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x$$

$$(\cos 2\omega - \cos x)^{\frac{1}{2}}\}^{-2} \cos^2 x\, dx$$

$$\cos \tfrac{1}{2}x(\cos 2\omega + \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}^{-1} \cos x\, dx$$

$$\{(\cos^2 2\omega - \cos^2 x)^{\frac{1}{2}} + \sin x \cos 2\omega\}\, (\cos^2 2\omega - \cos^2 x)^{-\frac{1}{2}}$$

$$\text{os}\, \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}^{-1} \cos x\, dx$$

$$\{\cos \tfrac{1}{2}x(\cos 2\omega + \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}^{-1} \cos x\, dx$$

$$\text{in}\, x \cos x \cos 2\omega(\cos^2 2\omega - \cos^2 x)^{-\frac{1}{2}}\, \{\cos \tfrac{1}{2}x$$

$$(\cos 2\omega + \cos x)^{\frac{1}{2}} - \sin \tfrac{1}{2}x(\cos 2\omega - \cos x)^{\frac{1}{2}}\}^{-1} \cos x\, dx$$

$$\therefore \int_{\theta}^{\frac{\pi}{2}} \tan^{-1}\left[\sin\omega \tan\tfrac{1}{2}\left\{\sin^{-1}(\cot\tfrac{1}{2}x\tan\omega)+\sin^{-1}(\tan\tfrac{1}{2}x\tan\omega)\right\}\right] \sin x\,dx$$

$$= \cos\theta\tan^{-1}\left[2^{-\frac{1}{2}}\sec\theta\left\{\sin\tfrac{1}{2}\theta(\cos\theta+\cos 2\omega)^{\frac{1}{2}}-\cos\tfrac{1}{2}\theta(\cos 2\omega-\cos\theta)^{\frac{1}{2}}\right\}\right]-2^{-\frac{1}{2}}\left\{\sin\tfrac{1}{2}\theta(\cos 2\omega+\cos\theta)^{\frac{1}{2}}-\cos\tfrac{1}{2}\theta(\cos 2\omega-\cos\theta)^{\frac{1}{2}}\right\}+\sin^2\omega\left\{\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega)-\sin^{-1}(\sin\tfrac{1}{2}\theta\sec\omega)\right\};$$

$\therefore$ from equations (4), (5), and (6), chance of conditions being fulfilled under this subcase,

$$= 2\pi^{-1}\Big\{\sin\omega\cos\tfrac{1}{2}\theta(\cos^2\omega-\cos^2\tfrac{1}{2}\theta)^{\frac{1}{2}}-\sin\omega(\cos^2\omega-2\cos^2\tfrac{1}{2}\theta)\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega)-\sin\omega\sin\tfrac{1}{2}\theta(\cos^2\omega-\sin^2\tfrac{1}{2}\theta)^{\frac{1}{2}}+\sin\omega(\cos^2\omega-2\sin^2\tfrac{1}{2}\theta)\sin^{-1}(\sin\tfrac{1}{2}\theta\sec\omega)+\cos\theta\sin^{-1}(\tan\tfrac{1}{2}\theta\tan\omega)-2\sin\omega\sin^{-1}(\sin\tfrac{1}{2}\theta\sec\omega)-\tan^{-1}\left\{\cot\omega\,(\operatorname{cosec}^2\tfrac{1}{2}\theta-\sec^2\omega)^{\frac{1}{2}}\right\}+\cos\theta\sin^{-1}(\cot\tfrac{1}{2}\theta\tan\omega)+2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega)+\tan^{-1}\left\{\cot\omega(\sec^2\tfrac{1}{2}\theta-\sec^2\omega)^{\frac{1}{2}}\right\}-4\sin\omega\cos\theta\tan^{-1}\left[2^{-\frac{1}{2}}\sec\theta\left\{\sin\tfrac{1}{2}\theta(\cos\theta+\cos 2\omega)^{\frac{1}{2}}-\cos\tfrac{1}{2}\theta(\cos 2\omega-\cos\theta)^{\frac{1}{2}}\right\}\right]+2^{\frac{1}{2}}\sin\omega\left\{\sin\tfrac{1}{2}\theta(\cos 2\omega+\cos\theta)^{\frac{1}{2}}-\cos\tfrac{1}{2}\theta(\cos 2\omega-\cos\theta)^{\frac{1}{2}}\right\}-4\sin^3\omega\left\{\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega)-\sin^{-1}(\sin\tfrac{1}{2}\theta\sec\omega)\right\}\Big\}\quad\ldots\quad\ldots\quad(7)$$

9. $\therefore$ from equations (2), (3), and (7), total chance of conditions being fulfilled $= 2\tan^2\omega$

$$+2\pi^{-1}\sin\omega\Big[\cos 2\omega\tan^{-1}\left\{\operatorname{cosec}\omega\cot\omega\,(\sin^2\tfrac{1}{2}\theta-\tan^2\omega)^{\frac{1}{2}}\right\}-\cos\theta\cos^{-1}\left\{\sin\omega\tan\omega\,(\sin^2\tfrac{1}{2}\theta-\sin^2\omega)^{-\frac{1}{2}}\right\}-2\sin\omega\tan\omega\,(\sin^2\tfrac{1}{2}\theta-\tan^2\omega)^{\frac{1}{2}}\Big]$$

$$+4\pi^{-1}\sin^2\tfrac{1}{2}\theta\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}\theta)-2\tan^2\omega+4\pi^{-1}\tan\omega\,(\sin^2\tfrac{1}{2}\theta-\tan^2\omega)^{\frac{1}{2}}$$

$$+2\pi^{-1}\Big\{\sin\omega\cos\tfrac{1}{2}\theta\,(\cos^2\omega-\cos^2\tfrac{1}{2}\theta)^{\frac{1}{2}}-\sin\omega\,(\cos^2\omega-2\cos^2\tfrac{1}{2}\theta)\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega)$$

$$-\sin\omega\sin\tfrac{1}{2}\theta\,(\cos^2\omega-\sin^2\tfrac{1}{2}\theta)^{\frac{1}{2}}+\sin\omega\,(\cos^2\omega-2\sin^2\tfrac{1}{2}\theta)\sin^{-1}(\sin\tfrac{1}{2}\theta\sec\omega)$$

$$+\cos\theta\sin^{-1}(\tan\tfrac{1}{2}\theta\tan\omega)-2\sin\omega\sin^{-1}(\sin\tfrac{1}{2}\theta\sec\omega)-\tan^{-1}\left\{\cot\omega\,(\operatorname{cosec}^2\tfrac{1}{2}\theta-\sec^2\omega)^{\frac{1}{2}}\right\}$$

$$+\cos\theta\sin^{-1}(\cot\tfrac{1}{2}\theta\tan\omega)+2\sin\omega\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega)+\tan^{-1}\left\{\cot\omega\,(\sec^2\tfrac{1}{2}\theta-\sec^2\omega)^{\frac{1}{2}}\right\}$$

$$-4\sin\omega\cos\theta\tan^{-1}\left[2^{-\frac{1}{2}}\sec\theta\left\{\sin\tfrac{1}{2}\theta\,(\cos\theta+\cos 2\omega)^{\frac{1}{2}}-\cos\tfrac{1}{2}\theta\,(\cos 2\omega-\cos\theta)^{\frac{1}{2}}\right\}\right]+2^{\frac{1}{2}}\sin\omega\left\{\sin^{\frac{1}{2}}\theta\,(\cos 2\omega+\cos\theta)^{\frac{1}{2}}-\cos\tfrac{1}{2}\theta\,(\cos 2\omega-\cos\theta)^{\frac{1}{2}}\right\}-4\sin^3\omega\left\{\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega)-\sin^{-1}\sin\tfrac{1}{2}\theta\sec\omega)\right\}$$

T

$$\text{in}^2\frac{\theta}{2}\sin^{-1}(\tan\omega\operatorname{cosec}\tfrac{1}{2}\theta)+2\pi^{-1}\sin\omega(\cos 2\omega-\cos\theta)$$
$$\cos^{-1}\{2^{\frac{1}{2}}\sin\omega\tan\omega(\cos 2\omega-\cos\theta)^{-\frac{1}{2}}\}$$
$$\text{in}\,\omega(\sin^2\tfrac{1}{2}\theta-\tan^2\omega)^{\frac{1}{2}}+4\pi^{-1}\cos^2\tfrac{1}{2}\theta\sin^{-1}(\tan\tfrac{1}{2}\theta\tan\omega)$$
$$-4\pi^{-1}\sin^2\tfrac{1}{2}\theta\sin^{-1}(\cot\tfrac{1}{2}\theta\tan\omega)$$
$$\text{in}\,\omega(3\cos^2\omega-2\sin^2\tfrac{1}{2}\theta)\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega)-2\pi^{-1}$$
$$(3\cos^2\omega-2\cos^2\tfrac{1}{2}\theta)\sin^{-1}(\sin\tfrac{1}{2}\theta\sec\omega)$$
$$\sin\omega\{\sin\tfrac{1}{2}\theta(\cos 2\omega+\cos\theta)^{\frac{1}{2}}-\cos\tfrac{1}{2}\theta(\cos 2\omega-\cos\theta)^{\frac{1}{2}}\}$$
$$-8\pi^{-1}\cos\theta\sin\omega\tan^{-1}[2^{-\frac{1}{2}}\sec\theta\{\sin\tfrac{1}{2}\theta(\cos 2\omega+\cos\theta)^{\frac{1}{2}}$$
$$-\cos\tfrac{1}{2}\theta(\cos 2\omega-\cos\theta)^{\frac{1}{2}}\}].$$

We will now find the expansion of this in terms of ω as
.

$\theta=2\sin^{-1}[\frac{1}{8}\{8-5\cos^2\omega-\cos\omega(25\cos^2\omega-16)^{\frac{1}{2}}\}]^{\frac{1}{2}}$ from
uality (1)

$$=2\sin^{-1}\left\{\tfrac{1}{8}\omega^2\left(\frac{32}{3}-\frac{64\omega^2}{27}\right)\right\}^{\frac{1}{2}}q.p.$$
$$=2\sin^{-1}\{3^{-\frac{1}{2}}2\omega(1-\tfrac{1}{9}\omega^2)\}\,q.p.$$
$$=4\cdot 3^{-\frac{1}{2}}\omega(1+\tfrac{1}{9}\omega^2)\,q.p.$$

$\therefore$ the fifth term $= \frac{16}{9}\omega^2 \; q.p.$

$$3\cos^2\omega - 2\sin^2\tfrac{1}{2}\theta = 3 - \tfrac{17}{3}\omega^2 \; q.p.$$

$$\sin^{-1}(\cos\tfrac{1}{2}\theta\sec\omega) = \sin^{-1}(1 - \tfrac{1}{6}\omega^2) \; q.p.$$

$$= \tfrac{1}{2}\pi - 3^{-\frac{1}{2}}\omega + \text{terms in } \omega^3 \,;$$

$\therefore$ the sixth term $= 3\omega - 2 \,.\, 3^{\frac{1}{2}} \,.\, \pi^{-1}\omega^2 - \frac{37}{6}\omega^2$

$$3\cos^2\omega - 2\cos^2\tfrac{1}{2}\theta = 1 - \frac{\omega^2}{3} \; q.p.$$

$$\sin^{-1}(\sin\tfrac{1}{2}\theta\sec\omega) = \sin^{-1}(2 \,.\, 3^{-\frac{1}{2}}\omega) \; q.p.$$

$$= 2 \,.\, 3^{-\frac{1}{2}}\omega \; q.p. \,;$$

$\therefore$ the seventh term $= 4 \,.\, 3^{-\frac{1}{2}}\pi^{-1}\omega^2$

$$\cos 2\omega + \cos\theta = 2 + \text{terms in } \omega^2 \,;$$

$\therefore \sin\frac{1}{2}\theta\,(\cos 2\omega + \cos\theta)^{\frac{1}{2}} - \cos\frac{1}{2}\theta\,(\cos 2\omega - \cos\theta)^{\frac{1}{2}}$

$$= 3^{-\frac{1}{2}}\omega + \text{terms in } \omega^3 \,;$$

$\therefore$ the eighth term $= 2 \,.\, 3^{\frac{1}{2}} \,.\, \pi\omega^2 \; q.p.$

and $\tan^{-1}\{\sin\frac{1}{2}\theta\,(\cos 2\omega + \cos\theta)^{\frac{1}{2}} - \cos\frac{1}{2}\theta\,(\cos 2\omega - \cos\theta)^{\frac{1}{2}}\}$

$$= \frac{\omega}{\sqrt{3}} + \text{terms in } \omega^3 \,;$$

$\therefore$ the ninth term $= 8 \,.\, 3^{-\frac{1}{2}} \,.\, \pi^{-1}\omega^3 \; q.p.$

Collecting these terms and giving them their proper signs we get total chance $= 3\omega - \frac{11}{2}\omega^3 \; q.p.$

11. This is with the inradius expressed in radians. Putting ω radians $= \delta$ degrees

we get chance $= \frac{1}{60}\pi\delta - \frac{11}{2 \times 180^3}\pi^3\delta^3$

$$= \cdot 0524\delta - \cdot 000029\,\delta^3 \; q.p.$$

Putting $\delta = 4$ we get chance $= \cdot 202 \; q.p.$;

putting $\delta = 1$ we get chance $= \cdot 052 \; q.p.$

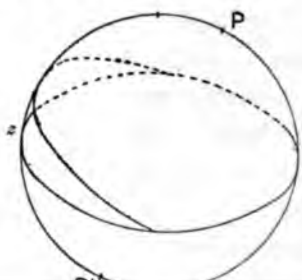
12. That the paths of three meteors should appear to meet in a point is not, however, a sufficient condition for their appearing to give a radiant. It is also necessary, (*a*) that the points at which they first appear should all be within 90° of one of the two points where their paths appear to meet, (*b*) that they should all be proceeding away from this point of meeting of their paths. Assuming that one direction is as probable as the other for each meteorite, the chance of the second of these conditions being fulfilled is clearly $\frac{1}{8}$.

13. To find the probability of the first being fulfilled let the zenith distance of P, one of the points of intersection of their

e z (fig. 3), then the area of that portion of the visible the celestial sphere which is within 90° of P is clearly

case now begins to present some difficulty, but, as a ssumption, I will take a uniform distribution of points of tion P, and also a uniform distribution of starting points. ner of these clearly agrees with my former assumption of n distribution of tracks.

the chance of any one of the starting points of meteorites vithin 90° of P will be $\pi^{-1}(\pi - z)$, and the chance of the



15. According to these results the process of determining a radiant from three meteors is in general sound, though the chance of at least one radiant of this sort being found among several meteors may be considerable. This and similar questions I may profitably leave to those of a greater practical acquaintance with the subject.

On the Variable Star Y Aurigæ (Ch. 1929).
By A. Stanley Williams.

$$\text{R.A.} = 5^{h}\ 18^{m}\ 20^{s},\ \text{Decl.} = +42^{\circ}\ 18'\!\cdot\!5\ (1855)$$
$$\text{,,} \quad = 5\ 21\ 32,\ \text{,,} \quad = +42\ 21'\!\cdot\!1\ (1900)$$

When the unknown period of a variable star is longer than a few days there is usually little difficulty in ascertaining its real length, since both this and the form of the light curve can generally be derived directly from the observations made night by night. There is likewise not usually any very great difficulty when the period is much less than a day, for then the variation is so rapid that the observations of a few consecutive hours are sufficient to indicate the correct period. It is when the period falls between about one day and four or five days that the most difficulty arises, and the difficulty is intensified when the increase in brightness is much more rapid than the decrease, since in such cases a marked change in the brightness of the star may be noticed in a few hours, giving rise to the impression that the period is a much shorter one than it really is. The variable *Y Aurigæ* belongs to this last-mentioned class. In the *Astronomische Nachrichten*, No. 3708, the period of this star was stated by the writer to be $0^{d}\!\cdot\!7925$, this period satisfying all the data at the time available, whilst some observations made during the increase seemed to show that the period must be a very short one, there being a considerable increase in brightness in the course of three or four hours. But recently, upon reducing the observations of this star made here during the past four years, it was found that this very short period failed to satisfy them for any very long interval of time; nor could any variation of the same very short period be made to do so. On the other hand, a period of $3^{d}\!\cdot\!862$, or thereabouts, seemed to satisfactorily represent all the observations. The present paper contains a discussion of the observations made here during the last four years, and in order that the whole of the evidence as to the real period and light curve may be accessible, the actual observations have been stated in full.

The observations in question were all made with a power of 75 on a $2\frac{1}{4}$-inch refractor, and in order to eliminate the effects

tion error" the observer's head was always so held that were parallel to a line joining the two stars BD. +42° 1298 +42° 1291, the last-mentioned star being to the left. parison stars used and the adopted light scales and des are given in the following table :—

TABLE I.

Comparison Stars.

Name.	BD. Mag.	Light Scale.			Adopted Magnitude.
		$a-1$.	$a-2$.	b.	
D. + 42° 1291	8·2	...	27·4	31·6	8·19
D. + 42 1305	9·0	15·4	23·4	...	8·47
D. + 42 1301	9·0	12·1	17·7	21·9	8·85
D. + 42 1297	9·5	6·4	7·9	7·2	9·52
D. + 42 1302	9·4	5·0	·5·0	5·0	9·72

e 4th, 5th, and 6th columns of the above table are three light scales, that headed $a-1$ being derived from the ions of 1901, and that $a-2$ from the observations of

Table II.

Observations.

No.	Date.		G.M.T.		J.D. 241.	Observations.	Brightness (a−1).	Mag.	
	1901.		h	m					
1	Feb.	6	15	30	5422·65	v 2 b, v 2 c, f 5 v, l 8 v	7·5	9·40	
2		11	13	15	5427·55	b 1 v o c	5·1	9·69	
3		13	13	00	5429·54	v 3 b, v 3 c, f 2 v, l 5 v	9·4	9·17	(1)
4		20	12	45	5436·53	v 7 b, v 9 c, v o f	12·7	8·78	
5	Mar.	1	12	15	5445·51	v 1 b, v 3 c	7·7	9·38	
6		3	13	00	5447·54	v 1 f, v 6 b, v 7 c	12·5	8·80	
7		12	11	40	5456·49	l 5 v 5 b, f 1 v 6 c	11·1	8·97	(2)
8		13	12	15	5457·51	b 2 v	4·4	9·77	(3)
9		18	11	10	5462·47	b o v 1 c	6·3	9·55	
10		21	12	45	5465·53	b 1 v o c	5·1	9·69	
11		22	10	30	5466·44	b o v 2 c	6·5	9·52	
12		24	11	00	5468·46	v 1 b, v 2 c	7·2	9·44	(4)
13		25	11	30	5469·48	b o v 1 c	6·3	9·55	
14		26	10	10	5470·42	v 3 b, v 4 c	9·2	9·20	
15			11	55	5470·50	f 1 v 5 b, v 6 c	11·2	8·96	
16			12	55	5470·54	f o v 6 b, v 7 c	12·2	8·84	
17		27	10	10	5471·42	v 1 f, v 6 b	12·8	8·77	
18			11	55	5471·50	v 1 f, v 6 b	12·8	8·77	(5)
19		28	11	00	5472·46	f 3 v 2 b, v 3 c	8·6	9·27	
20			12	30	5472·52	f 4 v 2 b, v 3 c	8·2	9·32	
21		29	10	15	5473·43	b o·5 v o c, f 6 v	5·3	9·67	(6)
22		31	10	00	5475·42	f o ± v 5 b	11·4	8·93	(7)
23	Apr.	1	10	00	5476·42	f 3 v 2 b, v 3 c	8·6	9·27	
24			12	00	5476·50	f 5 v o·5 b	6·9	9·47	
25		4	9	50	5479·41	v 3 b	9·4	9·17	(8)
26		12	9	50	5487·41	f 1 v 4 b, v 5 c	10·7	9·02	
27		13	10	30	5488·44	b 1 v	5·4	9·65	
28		14	9	05	5489·38	b 1 v	5·4	9·65	
29		15	10	00	5490·42	v 2 f, v 7 b	13·7	8·66	
30		17	9	50	5492·41	b 1 v	5·4	9·65	(9)
31		18	9	40	5493·40	v o ± b	6·4 ±	9·53 ±	(10)
32		19	9	45	5494·41	v 1 f, v 6 b	12·7	8·78	
33		20	9	45	5495·41	f 3 v 2 b, v 5 c	8·7	9·26	
34		21	9	00	5496·38	b o v 2 c	6·7	9·50	
35		22	9	25	5497·39	v o b	6·4	9·53	
36			9	38	5497·40	v 1 b	7·4	9·41	

Date.	G.M.T.	J.D. 241.	Observations.	Bright-ness (a−1).	
1901.	h m				
Apr. 22	10 00	5497·42	v 2 b	8·4	9
	10 25	5497·43	v 3 b	9·4	9
23	9 00	5498·38	v 2 f, v 6 b	13·3	8
	11 00	5498·46	v 0·5 f, v 5 b	12·0	8
24	9 30	5499·40	v 2 b	8·4	9
25	9 35	5500·40	v 0 b	6·4	9
26	9 10	5501·38	v 1 b, v 3 c	7·7	9
	9 25	5501·39	f 2 v 3 b, v 5 c	9·8	9
	9 50	5501·40	f 0 v 4 b	11·2	8
	10 00	5501·42	f 0·5 v 5 b	11·5	8
	10 20	5501·43	v 0·5 f, v 6 b	12·5	8
	10 35	5501·44	v 2 f, v 7 b	13·7	8
	11 00	5501·46	v 2 f, v 7 b	13·7	8
28	8 50	5503·37	v 3·5 b	9·9	9
May 3	9 00	5508·38	b 1 v	5·4	9

No.	Date.		G.M.T.	J.D. 241.	Observations.	Brightness (a−1).	Mag.	
	1901.		h m					
75	Aug.	21	11 17	5618·47	f 3 v 3 b, (v 6 c)	9·3	9·19	(17)
76			14 15	5618·59	f 4·5 v 2·5 b, (v 7 c)	8·3	9·31	
77		22	12 08	5619·51	f 5·5 v o b, v 2 c	6·8	9·49	
78		23	11 35	5620·48	b 1 v 3 c, f 7 v	6·1	9·57	
79			14 15	5620·59	b 1 v, (v 5 c), f 7 v	5·3	9·67	
80		24	13 25	5621·56	v 2·5 f, v 8·5 b	14·7	8·54	
81		26	11 50	5623·49	v o b	6·4	9·53	
82		27	14 10	5624·59	f 1 v 5 b	11·2	8·96	
83	Sept.	1	11 05	5629·46	v 2 f, v 7 b	13·8	8·65	(18)
84		3	10 40	5631·44	f 3 v 3 b	9·3	9·19	
85		4	10 10	5632·42	f 5 v o b	6·5	9·52	
86		5	10 20	5633·43	f 2 v 3 b	9·8	9·13	(19)
87			11 18	5633·47	v 1 f, v 7 b	13·2	8·72	(19)
88			12 32	5633·52	v 3 f, v 8 b	14·8	8·53	
	1902.					Scale a−2.		
89	Mar.	4	12 25	5813·52	f 9 v, b 1 v	8·8	9·45	
90		5	11 50	5814·49	v 2 f, v 10 b, v 12 c	18·8	8·78	
91		6	12 15	5815·51	f 5 v 4·5 b, v 6 c	12·3	9·22	
92	Apr.	3	10 10	5843·42	v o b	7·9	9·52	(20)
93		6	10 45	5846·45	f 6 v 3 b, v 5 c	11·0	9·31	
94		24	9 15	5864·39	v 3 f, v 9 b, v 12 c	18·8	8·78	
95		27	9 45	5867·41	b 1·5 v 2 c, f 10 v	6·9	9·58	
96		28	9 15	5868·39	v 11 b 2 c, v 1 f	18·7	8·78	
97			10 18	5868·43	v 11 b 2 c, v 1 f	18·7	8·78	
98	July	28	13 00	5959·54	b 1 v	8·9	9·45	
99	Aug.	24	14 55	5986·62	b 2 v 3 c	6·8	9·59	
100		25	13 07	5987·55	f 2 v 7 b, v 12 c	16·8	8·91	
101		27	12 55	5989·54	f 10 v 3 b, v 6 c	10·0	9·37	
102		28	14 35	5990·61	b 1 v 4 c, f 10 v	7·6	9·54	
103	Sept.	6	12 10	5999·51	v 3 f, v 13 b	20·7	8·65	
104		7	11 10	6000·47	f 3 v 6 b	14·4	9·07	
105		8	12 17	6001·51	b o v 4 c	8·3	9·49	
106		26	11 15	6019·47	f o v 9 b, v 12 c	17·3	8·88	
	1903.							
107	Jan.	28	15 35	6143·65	f 5 v 7 b	13·7	9·12	
108	Mar.	21	12 27	6195·52	b 1 v 2 c	7·0	9·58	
109		22	11 27	6196·48	f 2 v 9 b	16·1	8·96	
110		26	11 10	6200·47	f 4 v 10 b	15·3	9·01	
111	Apr.	22	10 35	6227·44	f 2 v 8 b, v 9 c	15·5	9·00	

e.	G.M.T.	J.D. 241.	Observations.	Bright-ness (a−1).	Mag.	
	h m					
8	11 55	6548·50	f 4 v 8 b, v 9 c	14·4	9·07	(20)
10	12 30	6550·52	b 1 v 2 c	7·0	9·58	
22	11 45	6562·49	b 2 v 1 c	6·0	9·65	
	12 45	6562·53	b 0 v 3 c	7·9	9·52	
1	9 55	6572·41	f 7 v 2 b, v 4 c	10·0	9·37	
6	10 00	6577·42	b 1 v 2 c	7·0	9·58	
9	10 00	6580·42	f 10 v 0 b, v 2 c	7·7	9·53	
10	10 20	6581·43	b 2 v 0 c	5·2	9·70	
	11 50	6581·49	v 0 b	7·9	9·52	
11	10 00	6582·42	v 2 f, v 12 b	19·8	8·70	
12	10 00	6583·42	f 6 v 4 b	11·8	9·25	
13	10 00	6584·42	b 1 v 1 c	6·5	9·62	(21)
15	9 50	6586·41	v 1 f, v 11 b	18·1	8·78	(22)
16	10 05	6587·42	f 7 v 3 b, v 6 c	10·9	9·31	
17	10 03	6588·42	b 2 v 1 c	6·0	9·65	(23)
18	9 20	6589·39	b 2 v 0 c	5·2	9·70	

tions were nearly satisfied by a period of $3^d{\cdot}862$, an ephemeris was computed from the following elements (Elements I.) :—

$$\text{Maximum} = \text{J.D. } 2415420{\cdot}354 + 3^d{\cdot}862\ \text{E}$$

and the observations were formed into seven groups and plotted upon transparent squared paper according to the intervals by which they followed the computed times of maximum. Three of the resulting charts were then superimposed one upon the other, and a provisional mean light curve (A) carefully drawn. By means of this provisional mean light curve the times of seven mean or normal maxima were then determined from the observations for a date corresponding approximately to the middle of each group. The details of these mean maxima are given in Table III.

TABLE III

Provisional Mean Maxima.

E.	Mean Obs. Maximum.	Computed Maximum (II.).	O – C. d	No. of Obs.
9	J.D. 2415455·347	5455·371	−0·024	33
24	5513·373	5513·254	+0·119	30
51	5617·500	5617·445	+0·055	25
110	5845·000	5845·120	−0·120	9
150	5999·437	5999·476	−0·039	9
201	6196·185	6196·280	−0·095	5
299	6574·555	6574·428	+0·127	18

The following elements (Elements II.) were derived from the foregoing provisional mean maxima :—

$$\text{Maximum} = \text{J.D. } 2415420{\cdot}641 + 3^d{\cdot}8589\ \text{E}$$

and the computed times of maximum according to these elements and the residuals O—C are stated in columns 3 and 4 of the above table.

Table IV. contains the observations arranged in order of the time by which they follow the last preceding maximum computed by means of the above elements (II.). The first column gives the number of the observation in Table II., the second the interval following maximum, and the third the observed magnitude. In two or three cases, where several observations were made on the same night, mean values are given in this table. Observations followed by : may possibly have been affected by cloud. Those followed by :: were certainly so affected.

TABLE IV.

Observations in Order of Distance from Maximum.

	Mag.	No. of Obs.	Dist. from Max. d	Mag.	No. of Obs.	Dist. from Max. d	Mag.
3	8·44	91	1·26	9·22	126	2·39	9·65 :
3	8·65	54	1·31	8·99	34	2·42	9·50
2	8·78	93	1·33	9·31	84	2·42	[9·19]
6	8·78	107	1·39	9·12	10	2·44	9·69
0	8·96	125	1·39	9·31	58	2·45	9·53
4	8·78	33	1·45	9·26	98	2·51	9·45
5	8·70	57	1·45	[9·65::]	13	2·53	9·55
6	8·54	12	1·51	[9·44::]	42	2·58	9·53
9	9·00	129	1·51	9·33	99	2·58	9·59
2	8·66	64	1·57	[9·62]	61	2·59	9·53
3	9·01	41	1·58	[9·29::]	21	2·62	9·67 :
8	8·78 :	60	1·58	9·26	102	2·71	9·54
4	8·65 :	101	1·60	9·37	67	2·73	9·61

No. of Obs.	Dist. from Max. d	Mag.	No. of Obs.	Dist. from Max. d	Mag.	No. of Obs.	Dist. from Max. d	Mag.
128	3·43	9·53 :	115	3·51	9·52	43 to 49	3·60	8·89
35 to 38	3·44	9·41	100	3·51	8·91	6	3·75	8·80
114	3·47	9·65	14 to 16	3·54	9·00	69	3·76	8·71
65	3·48	9·13	62	3·59	9·47	94	3·83	8·78

Table V. is Table IV. condensed, the observations having been formed into groups of four * and the means taken. In forming these means the observations bracketed in Table IV. have been rejected. Nearly all of them are marked with either : or ::, indicating that they were respectively possibly or certainly affected by cloud. A few discordant observations not so marked are considered later on.

TABLE V.

Mean Observations.

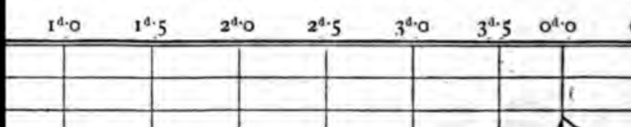
No. of Group.	Dist. from Max. d	Mag. from Curve.	Mag. from Obs.	C–O. mag.	No. of Group.	Dist. from Max. d	Mag. from Curve.	Mag. from Obs.	C–O. mag.
1	0·08	8·66	8·66	·00	14	2·03	9·50	9·48	+·02
2	0·24	8·74	8·74	·00	15	2·17	9·54	9·56	–·02
3	0·32	8·77	8·87	–·10	16	2·31	9·57	9·59	–·02
4	0·48	8·83	8·74	+·09	17	2·45	9·58	9·54	+·04
5	0·62	8·89	8·74	+·15	18	2·57	9·59	9·56	+·03
6	0·75	8·94	8·93	+·01	19	2·71	9·59	9·61	–·02
7	1·01	9·06	9·06	·00	20	2·90	9·60	9·57	+·03
8	1·16	9·13	9·13	·00	21	3·07	9·60	9·60	·00
9	1·29	9·19	9·19	·00	22	3·13	9·60	9·62	–·02
10	1·43	9·25	9·25	·00	23	3·27	9·57	9·54	+·03
11	1·62	9·32	9·29	+·03	24	3·40	9·44	9·54	–·10
12	1·72	9·36	9·27	+·09	25	3·50	9·27	9·24	+·03
13	1·88	9·43	9·45	–·02	26	3·71	8·89	8·93	–·04

The above observations having been plotted in diagram form, the mean light curve (B) reproduced in the adjoining figure was drawn. The magnitudes according to this curve are given in the above table next to the observed mean magnitudes, together with the differences C–O. It will be seen from the smallness of these differences in general,† and it will also appear on inspection of

* In the last three cases there are five observations to a group.

† The average difference C – O is ± 0·03 mag.

ram, that the observations are satisfactorily represented
iean light curve excepting at about $0^{d}\cdot5$ after maximum.
rvations in general appear to be represented quite as
i straight line as by anything else in the nature of a
urve between maximum and 2·2 days after that epoch,
i inclined to think that this is the true form, and that
rdances should be ascribed to errors of observation. As
of fact, the comparisons with the comparison star *f*
always been altogether satisfactory, and an additional
on star about midway in brightness between this star
much wanted. However, at least twice as many obser-
is those included in the present discussion are needed in
derive a perfectly satisfactory light curve, and it is
that the discordant observations at about half a day
ximum are not wholly due to errors of observation, but
icate the existence of a hump or secondary maximum.
st be left to future observation to decide.



With regard to the rejected observations, all of these are marked as being either certainly or possibly affected by cloud, with two exceptions. These are observations 64 and 84 of Tables II. and IV. A re-examination of the original records fails to indicate any reason why these two observations should be discordant. The differences from the mean light curve are respectively $-0^{m}\cdot39$ and $+0^{m}\cdot32$.

As the mean light curve B represented in the diagram differs to some extent from the provisional curve A, the times of the mean maxima have been determined again by means of the former curve. The observations were also plotted afresh on squared paper as reduced by the Elements II. The dates and times of these more definitive mean maxima as thus redetermined are stated in Table VI.

TABLE VI.

Definitive Mean Maxima.

E.	Obs. Mean Maximum.	Computed Maximum (III.).	O—C. d	No. of Obs.
9	J.D. 2415455·367	5455·371	−0·004	33
24	5513·343	5513·256	+0·087	30
51	5617·417	5617·449	−0·032	25
110	5845·130	5845·130	0·000	9
150	5999·407	5999·490	−0·083	9
201	6196·285	6196·299	−0·014	5
299	6574·525	6574·481	+0·044	18

And from the above revised times of maximum the following final elements (Elements III.) have been obtained by the method of least squares:—

$$\text{Maximum} = \text{J.D. } 2415420\cdot64 + 3^{d}\cdot8590 \text{ E.}$$

The computed times of maximum according to these elements are given in column 3 of Table VI., and the differences O—C in column 4. These differences are a little suggestive of the existence of a third term.

In the *A.N.* 3744 Dr. E. Hartwig published two observations of this star, made on 1901 July 25 and 26 respectively. The magnitude is given as 9·2 on both nights. The former of these observations is $1^{d}\cdot09$ and the latter $2^{d}\cdot09$, after the computed time of maximum, and the differences from the mean light curve B are $+0^{m}\cdot10$ and $-0^{m}\cdot31$ respectively. The star must have been low and in an unfavourable position for observation at the times of these observations, so that the differences are not greater than what might be expected under the circumstances.

TABLE VII.

Concluded Elements of Y Aurigæ.

of variation	$3^d.8590 = 3^d\ 20^h\ 36^m\ 58^s$
of maximum	1901 Feb. 4, $15^h\ 22^m$ G.M.T. = J.D. 2415420·64
num brightness	8·63 mag.
ium „	9·60 „
to maximum	$0^d\ 17^h\ 31^m$ *
num to minimum	$3^d\ 3^h\ 6^m$
of increase to decrease... ...	0·23

---

the Relative Brightness of Stars. By J. E. Gore.

parallax of a star is known, its absolute brightness, or amount of light emitted by the star in terms of the

1	2	3	4	5	6	7	8	
	R.A. 1900.	Dec. 1900.	Phot. Mag.	Parallax.	Spectrum.	Sun's mag. at Star's distance.	Relative Brightness.	Remarks.
	h m	° ′		″				
eiæ ...	0 3·8	+58 36	2·42	0·10*	F5G	5·07	11·49	
idge 34	0 12·7	+43 27	(7·9)	0·30	...	2·68	0·008	Proper motion = 2″·80
...	0 14·9	−65 28	4·34	0·15*	F8G	4·19	0·87	
...	0 20·5	−77 49	2·90	0·134*	G	4·43	4·09	Proper motion = 2″·28
eiæ ...	0 43·1	+57 17	3·64	0·154*	F8G	4·13	1·57	Mass = 1·6222 × Sun's mass
eiæ ...	1 1·2	+54 27	5·34	0·11	H	4·84	0·63	Proper motion = 3″·75
.. ...	1 18·5	+88 43	2·12	0·074	F8G	5·72	27·55	
i ...	1 34·0	−57 44	0·60	0·043	B5A	6·90	331·18	
... ...	1 39·4	−16 28	3·65	0·31*	G?	2·61	0·38	
i ...	3 15·9	−43 27	4·30	0·16	G5K	4·05	0·79	
ni ...	4 10·7	− 7 49	4·48	0·166*	H?	3·97	0·62	Proper motion = 4″·05
n ...	4 30·2	+16 18	1·06	0·107*	K5M	4·92	35·00	
Z. V., 243	5 7·7	−44 59	(8·5)	0·312*	...	2·60	0·004	Proper motion = 8″·70
... ...	5 9·3	+45 54	0·21	0·081*	G	5·48	128·23	Mass = 12·7 × Sun's mass
... ...	6 40·8	−16 35	−1·58	0·37*	A	2·23	33·42	Mass = 3·5465 × Sun
... ...	7 34·1	+ 5 29	0·48	0·325*	F5G	2·51	6·49	Mass = 3·627 × Sun
... ...	7 41·9	−33 59	5·42	0·064	...	6·04	1·75	
Maj. ...	8 54·2	+42 11	4·09	0·20	F5G	3·56	0·61	
5 ...	9 7·7	+53 7	(7·5)	0·14	H	4·34	0·054	
...	10 3	+12 27	1·34	0·022	B8A	8·36	642·7	
603 ...	10 5·3	+49 58	6·76	0·18	H	3·79	0·064	
ridge 1646	10 21·9	+49 21	6·54	0·11	A?	4·86	0·21	
5 ...	10 57·9	+36 38	7·60	0·47	...	1·71	0·004	Proper motion = 4″·75
3 ...	11 0·5	+44 2	(8·5)	0·24	...	3·17	0·007	Proper motion = 4″·40
ridge 1830	11 47·2	+38 26	6·47	0·15*	A?	4·19	0·122	Proper motion = 7″·05
t	12 10·0	− 9 43	6·05	0·14	E	4·34	0·207	
...	12 21	−62 32	1·05	0·05	B1A	6·57	165·96	
ri ...	13 56·8	−59 53	0·86	0·046	B1A	6·75	226·99	
...	14 11·1	+19 42	0·24	0·024	K	8·17	1486	
ri ...	14 32·8	−60 25	0·06	0·75*	G / K5M	0·69	1·786	Mass = 2·00 × Sun's mass
.. ...	16 23·3	−26 13	1·22	0·021	Ma	8·46	787·04	
is ...	17 30·2	+55 15	4·2	0·32	A?	2·54	0·216	
15 ...	17 37·0	+68 26	(9·0)	0·25	...	3·08	0·004	
chi ...	18 0·4	+ 2 31	4·07	0·16*	K	4·05	0·98	Mass = 2·939 × Sun

2	3	4	5	6	7	8	
R.A. 1900.	Dec. 1900.	Phot. Mag.	Parallax.	Spectrum.	Sun's mag. at Star's distance.	Relative Brightness.	Remarks
h m	° ′		″				
8 33·6	+38 41	0·14	0·082	A	5·50	139·32	
9 45·9	+ 8 36	0·89	0·231*	A5F	3·25	87·91	
1 2·1	+38 13	4·96	0·39*	H	2·11	0·07	Proper motio
1 9·6	+ 9 36	4·61	0·071*	F	5·81	3·02	Mass = 1·89 × Parallax f troscopic by Hussey
1 55·7	−57 12	4·74	0·28*	K5M	2·83	0·17	
2 1·9	−47 27	2·16	0·015	B5A	9·19	648·63	
2 52·1	−30 9	1·30	0·130	A3F	4·50	18·88	
2 59·4	−36 26	7·1	0·29	...	2·78	0·018	Proper motio

$$
\begin{aligned}
\Delta L = &- 0''.51 \,.\, \sin\{2^{\cdot}18(Y-1850^{\cdot}50)+130^{\circ}\} \\
&- 1^{\cdot}01 \,.\, \sin\{2^{\cdot}80(Y-1850^{\cdot}50)+240\} \\
&- 1^{\cdot}83 \,.\, \sin\{4^{\cdot}10(Y-1850^{\cdot}50)+200\} \\
&+ 0^{\cdot}24 \,.\, \sin\{5^{\cdot}03(Y-1850^{\cdot}50)+\ 46\} \\
&+ 1^{\cdot}29 \,.\, \sin\{6^{\cdot}40(Y-1850^{\cdot}50)+264\} \\
&+ 0^{\cdot}55 \,.\, \sin\{7^{\cdot}58(Y-1850^{\cdot}50)+153\} \\
&+ 0^{\cdot}92 \,.\, \sin\{9^{\cdot}69(Y-1850^{\cdot}50)+185\}\,.
\end{aligned}
$$

+ terms of shorter period than thirty-five years.

The notation explains itself, and the correction is to be subtracted from the tabular longitude. The two terms marked with an asterisk are Hansen's two faulty *Venus* terms, which have to be removed from the tables.

If the observations considered are restricted to those made at Greenwich since 1750, a mere inspection of the outstanding errors shows that they can be represented roughly by an inequality having a period of from seventy to ninety years, and reaching its maximum about 1825.

In my earliest researches of twenty years ago I employed the term

$$+2''{\cdot}80 \sin\{4^{\circ}{\cdot}5[Y-1807{\cdot}52]\}$$

because such a term does exist, and its coefficient had not then been determined. But experience showed that this term did not represent the observations with sufficient closeness, and failed to represent the observations made prior to 1750; so it was replaced by the two terms

$$+1''{\cdot}95 \sin\{2{\cdot}8[Y-1764{\cdot}0]\}$$
$$+2''{\cdot}69 \sin\{4{\cdot}1[Y-1802{\cdot}5]\}$$

Both represent arguments of actually existing terms whose values had not then been calculated.

Later the development of my theoretical work enabled me to extend the results to those given in the preceding expression, when the last seven inequalities which are expressed in terms of their annual increments do not depend on arbitrary arguments, but have had their annual motion and epoch fixed within narrow limits by their theoretical values.

But if purely empirical terms be employed with arguments of arbitrarily assigned motion and epoch, it is possible to represent the observed values by a thousand different combinations of two or three such terms. But this cannot be legitimate, and any term chosen to represent the outstanding tabular errors must be one that is theoretically possible, and so one whose epoch can be calculated from theory with some degree of approximation.

In addition to the two terms mentioned by Mr. Cowell as

rguments of the same period as that of the term he has from the observation there are a number of others, such hree depending on the arguments

$$\begin{array}{r} D \quad -15V+12E \\ 2D-4z+42V-40E \\ \varpi+\ 2E-\ 4M \end{array}$$

values of the coefficients of these terms as calculated by u's formulæ will be found to be much smaller than is by Mr. Cowell; but this will be the case with the t of every inequality of this period when so calculated. equation employed by M. Radau will not yield a t exceeding a second of arc to any possible term of this nless values be assigned to $\Delta b'$ or $\nabla b'$ respectively which eyond the maximum values of these functions.

bservatory: 1904 *December* 9.

The values of the corrected coefficients are exhibited in Table I.; the third columns refer to the Hansen period; periods 86–89 are common both to Airy and Hansen, and the results are enclosed in brackets, to call attention to this. In later stages of this paper the values taken for periods 86–89 are the means of the two sets of values here given, and the values for the 133 periods are then treated as continuous.

TABLE I.

Coefficients of sin g, cos g, corrected. Unit 0″·1.

Period.	sin g			cos g		
	0 +	48 +	85 +	0 +	48 +	85 +
+ 1	− 2	0	(−3)	+ 4	−10	(−10)
2	−10	0	(−5)	− 3	− 8	(− 5)
3	−10	0	(0)	+ 2	−14	(−18)
4	+ 4	+ 6	(+4)	− 3	−15	(−15)
5	+ 4	+ 9	+5	+ 6	+ 1	− 5
6	+ 6	− 5	+1	+ 3	− 6	− 9
7	+ 4	− 6	+2	− 1	− 5	− 1
8	− 4	+ 6	−7	− 1	− 7	0
9	− 4	− 5	−1	+ 6	− 8	− 3
10	− 1	+ 4	−5	+12	+ 7	− 4
11	−17	− 2	−5	+ 1	+ 3	−12
12	+ 7	+ 2	0	−13	− 3	− 5
13	− 7	− 4	+3	−14	+13	− 6
14	+ 1	− 7	+1	−12	− 4	− 5
15	+ 1	− 2	−3	− 6	0	+ 5
16	+ 7	0	−4	+ 4	+ 6	− 3
17	− 5	− 3	−3	0	− 2	− 6
18	− 1	+ 2	−2	−10	+ 4	− 5
19	− 5	− 9	+2	+ 2	− 1	− 5
20	+ 5	− 1	+3	+ 7	+ 1	− 4
21	− 2	− 2	0	+ 6	+ 1	0
22	+ 2	− 2	0	− 6	− 3	+ 3
23	− 1	+ 1	+2	− 9	+11	+ 1
24	+ 6	− 2	+1	− 6	+ 3	− 7
25	+ 9	− 9	−1	− 6	−10	− 3

sin g			cos g	
0	48	85	0	48
+	+	+	+	+
+14	+ 7	+2	+ 8	+ 1
− 6	+12	+6	+26	+ 1
− 1	+19	+1	− 3	+ 4
− 2	+ 4	+4	+ 4	+11
+ 3	0	+5	− 3	0
− 1	+ 2	−7	+ 1	+ 2
− 2	0	−3	−17	− 9
− 2	+ 2	+1	+ 6	+ 7
+17	− 3	−5	−16	+ 9
− 2	− 6	+2	− 9	− 5
− 4	− 1	+6	− 1	0
− 9	− 6	+4	− 7	+ 3
+ 4	(− 4)	−1	+ 4	(− 9)

I thus obtained, in units of 1″÷340, quantities for even and odd function analysis, which I exhibit in Table II.

TABLE II.

Coefficients of sin g and cos g arranged for Even and Odd Function Analysis.
Unit 1″÷340.

	sin g		cos g	
$\iota\sigma$.	Even.	Odd.	Even.	Odd.
0	−38	...	+ 42	...
1	−11	+45	+ 42	+16
2	− 1	+27	− 8	+54
3	+14	+ 6	− 29	+49
4	+57	−17	−111	+33
5	− 6	−46	−142	+16
6	−23	−33	−167	−33
7	− 3	−43	−160	−34
8	−33	− 3	− 89	−31
9	+23	−41	− 78	−24
10	+46	−18	− 16	+14
11	+32	−14	+ 20	+ 2
12	+25	+ 9	− 18	+38
13	−10	+30	− 4	+64
14	−31	+ 9	− 7	+41
15	−55	+23	+ 16	+18

Although there is the appearance of a run in Table II. in the coefficients of sin g, the quantities involved are exceedingly small (about 0″·1).

I have calculated the quantities x_j defined in my paper, lxv. November, with the following results:

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
sin g unit 1″÷340	−12	−25	+69	− 68	−7	− 26	−33	+ 17	+34
cos g unit 1″÷340	+53	+82	+37	+102	+3	−171	−94	+154	+58
Δg unit 1″÷20	+28	+43	+20	+ 54	+2	− 91	−50	+ 82	+31

A discordance between tables and observation in the coefficient of cos g implies a discordance nine times as great in the value of g. The third set of values given above has therefore been derived from the second by dividing by 17, to reduce the unit to 0″·05, and multiplying by 9.

t it is convenient to set down the tabular v
gitude &c. that have been employed.
nents are taken from Damoiseau's tables,
re reduced from Damoiseau's epoch, which
anuary 0·5—9^m $21^s·5$ G.M.T. to Hansen's e
ry 0·0 G.M.T. Next I copy Hansen's argum
☊, and calculate from them L, L′.

Jan. 0·0 M.T.			Coefficient of T.			Coefficients of T².	T
	′	″	rev. °	′	″	″	″
	3	28·70	1336 + 307	52	41·39	+ 10·723	+ 0·0
	19	47·63	1325 + 198	49	53·99	+ 50·418	+ 0·0
	43	49·40	5 + 134	9	57·63	− 6·563	− 0·0
	54	40·45	100 + ...	45	53·00	...	.
.	25	17·39	100 − ...	57	17·00	...	.
0	19	33·64	1325 + 198	50	37·15	+ 49·435	+ 0·0
...	24	28·22	100 − ...	56	32·18	− 0·561	.
192	7	21·91	16 + 243	12	2·07	− 44·323	− 0·0
246	13	50·28	5 + 135	51	38·09	− 6·518	− 0·0
326	43	28·85	5 + 134	8	59·61	− 8·189	− 0·0
		26·70	1336 + 307	53	39·61	+ 13·301	+ 0·0
				46	6·30	+ 1·110	.

On certain assumptions as to the nature of the long-period empirical term required it appears from the opening paragraphs of the paper quoted that a correction

$$-4''\cdot 3 \text{ or}$$
$$-4''\cdot 3+5''\cdot 2-3''\cdot 0\ \mathrm{T}\ -4''\cdot 4\ \mathrm{T}^2$$

is still required. Probably it is best to assume such a period for the empirical term as will make the secular acceleration equal to its theoretical value. The correction will then be about

$$-4''\cdot 3+\tfrac{1}{2}\{+5''\cdot 2-3\cdot 0\ \mathrm{T}\ -4''\cdot 4\ \mathrm{T}^2\}$$

to which we must add $+0''\cdot 8$ if the formula is to represent the observations after 1902·0, which are now reduced to the epoch of Newcomb's catalogue. The mean longitude is therefore

$$335°\ 43'\ 25''+(1336^{\mathrm{rev.}}+307°\ 53'\ 9'')\mathrm{T}+7''\cdot 3\ \mathrm{T}^2$$

subject to uncertainty of the order

$$\pm 5''\pm 3''\ \mathrm{T}$$

until theory has given a more precise value to the empirical terms.

Coming now to the mean anomaly, Professor Newcomb has applied the correction

$$-1''\cdot 14-29''\cdot 17\ \mathrm{T}-3''\cdot 76\ \mathrm{T}^2$$

in the *Nautical Almanac* since 1883. I have applied the same correction to the individual tabular places from 1847 to 1882. I have also applied (see *Monthly Notices*, vol. lxiv. p. 85)

$$+4''\cdot 63-13''\cdot 99\ \mathrm{T}+4''\cdot 743\ \mathrm{T}^2$$

to all tabular values of g based on Hansen. It will be seen that the value of g for the Hansen period has now been reduced to $-10''\cdot 5$ (a constant) in excess of that used by Airy.

Owing to a numerical error, in the first table of this paper I have applied $-11''\cdot 0$ to Airy's g; there is therefore a want of continuity of $0''\cdot 5$ in g, or Airy's tabular places require a further correction of $+0''\cdot 05 \cos g$. This is insensible.

In Table I. g also contains a long-period *Venus* term and Newcomb's empirical term of the same period. In my paper (*Monthly Notices*, vol. lxv. November) I came to the conclusion that Newcomb's empirical term had too short a period. Removing it therefore by applying to the x's (see *Monthly Notices*, vol. lxv. p. 51)

+532		−69		+2		−1		−2
	+316		−19		0		0	

…r the x's of Δg

	−49	+4	−51	+29	
+359	+35	−91	+82		

… value +359 of x_2 be attributed to a secular term i…
…d obtain a concluded value entirely at variance w…
Analogy with the long-period *Venus* term leads us…
…that the cause that produces the empirical term in t…
…le will also produce the same term in the mean anoma…
…fore apply the x's of my long-period empirical term (…
…y *Notices*, vol. lxv. p. 51), which are :

−464	+32	o	o	o
−237	+8	o	o	

…ining for the corrected x's of g

+96	−17	+4	−51	+29
+122	+43	−91	+82	

… way of treating the subject is to form the x'…
… of perigee. These are :

−13

This requires correction by

$$+86\,t_1+86\,t_2$$

or by Constant $+\,2''\cdot 7\,\mathrm{T}+7''\cdot 4\,\mathrm{T}^2$, measuring T from 1826

or by Constant $-\,1''\cdot 0\,\mathrm{T}+7''\cdot 4\,\mathrm{T}^2$, measuring T from 1800.

To find the constant, the mean of the quantities in Table III. (*Monthly Notices*, vol. lxv. p. 39) is $-1''\cdot 35$; the mean of the quantities in the last column of the first table of this paper is $-0''\cdot 185$, corresponding to $\Delta g = -1''\cdot 67$; the mean value of the correction to ϖ must therefore be $-0''\cdot 32$; the constant is therefore $-3''\cdot 7$, to which must be added $+0''\cdot 8$ for the epoch of Newcomb's catalogue. The concluded value therefore exceeds Hansen's by

$$-7''\cdot 5+13''\cdot 0\,\mathrm{T}+2''\cdot 7\,\mathrm{T}^2$$

or

$$\varpi = 225^\circ\ 23'\ 46''+(11^{\mathrm{rev.}}+109^\circ\ 3'\ 15'')\mathrm{T}-33''\,\mathrm{T}^2$$

with possible errors of $3''$ in the mean motion for 1826 and $7''$ in the secular term, and perhaps $2''$ in the value for 1875.

Reducing the motion of the perigee to 1850 and subtracting $5024''$ for precession, I obtain for the observed sidereal motion of the perigee

$$14643538'' \text{ with a possible error of } \pm 6''.$$

Professor Brown (*Monthly Notices*, vol. lxiv. p. 532) quotes $14643523''$ as the observed value, which agrees more closely with his theoretical values than the observed value found by me.

My phrase "possible error" may be approximately taken to mean three times the probable error. I am assuming 20, 35, 46, 13, 39, 21, 68 to be accidental errors, and I am taking 80 as the measure of the "possible error."

As this paper concludes my discussion of the longitude I here give a summary of the results obtained.

1. Certain constants have been measured.

2. Table VIII. (*Monthly Notices*, vol. lxv. December) shows a close agreement between theory and observations as regards short-period terms. Probably there is no unknown term with coefficient $0''\cdot 4$ or more having a mean motion differing by less than $0^\circ\cdot 4$ a day from the mean motion of any one of the 40 auxiliary angles of that paper.

3. An apparent exception, depending on the argument $g+\omega-\omega'$ or possibly $g+\varpi$ is probably to be attributed to errors of north polar distance.

4. The coefficient ($6''\cdot 6$) of sin ☊, the principal figure of Earth term, is decidedly smaller than the latest theoretical value. ($7''\cdot 7$ G. W. Hill.)

5. Certain empirical terms have been obtained (*Monthly Notices*, vol. lxv. November).

...nal Values of the Coefficients in the New Lunar Theory.

By Ernest W. Brown, Sc.D., F.R.S.

As has been stated on previous occasions the problem ...consideration, and now completed, is that of Delaunay's ..., with the additional terms introduced by replacing ... $a(E-M)/a'(E+M)$. In earlier papers * I have given a ...l account of the methods used and of the means taken to ... accuracy, with some indication of the extent to which the ... conform with those deduced from observation. The main ... of the present communication is to give the complete ...ical values of the coefficients of all periodic terms in ...ude and latitude which are as great as 0″·01, and in ...x those which are as great as 0″·001. Every coefficient ...en taken to at least one more place in the computations.

...secondary object is to compare the results with those of ...n, so as to show explicitly the extent of the agreement ...en the two theories. The results of Delaunay may be used ...eck where differences from those of Hansen occur; but ...convergence makes so many of Delaunay's coefficients

2. *The Constants of the Theory.*—The numerical values of the constants used in reducing the theory to numbers are as follows:

MOON (1850·0).	SUN (1850·0).
$n = 17\ 325\ 594''{\cdot}06$	$n' = 1\ 295\ 977''{\cdot}415$
$e = {\cdot}054\ 900\ 56$	$e' = {\cdot}016\ 771\ 91$
$\gamma = {\cdot}044\ 887\ 16$	$\gamma' = 0$
$\frac{1}{a} = 3412''{\cdot}596$	$\frac{1}{a'} = 8''{\cdot}7800$

$$\frac{E}{M} = 81{\cdot}500.$$

The definitions of these constants are those adopted by Delaunay.

The object here being the comparison of the two sets of *theoretical* coefficients and not the comparison of either with the observed values, Hansen's coefficients are given directly from Newcomb's results, referred to above, and the changes which they require when Hansen's constants are altered to the values just given are shown separately. The comparison of the values for e, γ, a is seen directly from the coefficients of sin l and sin F and cos 0 in the longitude, latitude, and parallax respectively. Hansen's $e' = {\cdot}016\ 792\ 28$, and his $1/a' = 8''{\cdot}848$. His values for n, n' are the same as mine within the limits of accuracy of the comparison.*

3. *Explanation of the Tables Below.*—The *first* column gives the principal characteristic (C) of each set of terms. In the *second*, *third*, *fourth*, and *fifth* columns are the multiples of l, l', F, D (Delaunay's notation), which enter into the arguments; the characteristic and multiples of l, l', F being the same for each set of terms (that is, for those terms whose arguments differ only by multiples of 2D), they are only set down for the first term of each set. The *sixth* column (headed B) contains my final values. The *seventh* column (headed H) contains Hansen's theoretical values, with his constants. The *eighth* column gives the reduction (R) necessary to reduce Hansen's results to my set of constants. The *last* column (B—H—R) shows the real differences between the results of the two theories. The coefficients to which letters are attached are discussed in the following section.

4. *Observations on the Results.*—As has been stated the calculations were constructed so as to include all coefficients in longitude and parallax as great as $0''{\cdot}01$, and to neglect all characteristics which did not have at least one coefficient as large as this amount. But since the calculations in each characteristic included all coefficients of $0''{\cdot}0005$ and over, there are com-

* A typographical error occurs on p. 526, where Newcomb's coefficient for the principal elliptic inequality is set down as $22659''{\cdot}58$; it should, of course, be $22639''{\cdot}58$.

ly few lying between 0″·005 and 0″·01 (which are of
ntered as equal to 0″·01) present in Hansen's theory and
mine. In longitude there are but two, and for one of
aracteristic e^6 and argument $6l$, the elliptic value suffices;
r (0″·01) has the characteristic $e^3e'\gamma^2$, and Hansen and
y agree on its value. In latitude there are two, with
ristic $\gamma e^4e'$, to which the previous remark also applies.
parallax similar remarks may be made with the degree
acy 0″·001 at the start; there are three such coefficients,
ristic e^4e', each having a coefficient, according to Hansen,
1, and they are probably less than 0″·001 and greater
0005. These are, of course, quite unimportant from a
point of view, and they really only need consideration
e number of them is comparatively large. It is, therefore,
interest to know the sum of the absolute values of the
es B−H−R in each coordinate to obtain an idea of
imum differences which tables constructed on the two
would show. Adding the numbers in the columns
R, without regard to sign, we obtain

n longitude	3″·61
n latitude	1·90

confirms my value within the limits of possible error of the estimate.

In the coefficients, marked (*c*), the differences are $0''\cdot23$ in a coefficient $1''\cdot09$, and $0''\cdot21$ in a coefficient $1''\cdot30$. Newcomb estimates $0''\cdot87$ and $1''\cdot39$ as Delaunay's complete values for the respective coefficients, but any estimates must be uncertain by at least the differences between the two sets of results. The periods are long and the coefficients are difficult to determine by any method in which approximation along powers of m is used. Even with the method of this theory the loss of accuracy owing to small divisors is so great that these two coefficients to a certain extent determine the number of places of decimals to be adopted at the outset of the whole work.*

It is not evident why the differences marked (*f*), which depend mainly on γ, practically disappear if we adopt $18461''\cdot5$ instead of $18463''\cdot3$ for the principal term in latitude of Hansen's theory, other differences being not materially affected. It would almost appear as though a value near the former was really the constant of Hansen's theory, especially as these coefficients are easy to determine accurately.

True Longitude—Mean Longitude. Coefficients of Sines.

C.	*l*.	*l'*.	F.	D.	B.	H.	R.	B−(H+R).
1	0	0	0	6	+ $0''\cdot13$	+ ·13	...	...
				4	+ 13·90	+ 13·90	...	...
				2	+ 2369·90	+ 2369·75	− ·01	+ ·16 (*a*)
e	1	0	0	6	+ ·02	+ ·02	...	...
				4	+ 1·98	+ 1·98	...	...
				2	+ 191·95	+ 191·95	...	...
				0	+ 22639·58	+ 22640·15	− ·57	...
				−2	− 4586·44	− 4586·56	+ ·11	+ ·01
				−4	− 38·43	− 38·43	...	...
				−6	− ·39	− ·40	...	+ ·01
e'	0	1	0	4	− ·29	− ·29	...	...
				2	− 24·45	− 24·45	+ ·03	− ·03
				0	− 668·94	− 669·85	+ ·81	+ ·10
				−2	− 165·35	− 165·22	+ ·20	− ·03
				−4	− 1·88	− 1·89	...	+ ·01
				−6	− ·02	− ·02	...	...
a	0	0	0	5	·00	+ ·01	...	− ·01
				3	+ ·40	+ ·41	...	− ·01
				1	− 124·79	− 125·43	+ ·96	− ·32 (*b*)

* See a paper by the writer, "On the Small Divisors in the Lunar Theory," *Trans. Amer. Math. Soc.* vol. iii. (1902), pp. 159–185. The transformations given in sect. iii. of the paper were unfortunately only worked out after most of the calculations had been completed, so that they have not been used for computation.

True Longitude—Mean Longitude. Coefficients of Sines.

l.	l'.	F.	D.		B.		H.	R.	B-
2	0	0	4	+	″ ·21	+	·22	...	
			2	+	14·39	+	14·38	...	
			0	+	769·02	+	769·06	−·04	
			−2	−	211·66	−	211·71	+·01	
			−4	−	30·77	−	30·78	...	
			−6	−	·57	−	·57	...	
			−8	−	·01		...	...	
1	1	0	4	−	·05	−	·05	...	
			2	−	2·93	−	2·93	...	
			0	−	109·80	−	109·92	+·14	
			−2	−	206·22	−	206·46	+·26	
			−4	−	4·40	−	4·41	+·01	
			−6	−	·07	−	·07	...	
1	−1	0	6	+	·01		...	...	
			4	+	·28	+	·29	...	
			2	+	14·60	+	14·60	−·02	

True Longitude—Mean Longitude. Coefficients of Sines.

C.	l.	l'.	F.	D.		B.		H.	R.	B−(H+R).
e^3	3	0	0	4	+	″ ·02	+	·02	...	...
				2	+	1·06	+	1·06	...	...
				0	+	36·12	+	36·13	...	−·01
				−2	−	13·19	−	13·19	...	...
				−4	−	1·19	−	1·18	...	−·01
				−6	−	·29	−	·29	...	...
				−8	−	·01		...	...	−·01
e^2e'	2	1	0	4	−	·01		...	...	−·01
				2	−	·29	−	·29	...	...
				0	−	7·66	−	7·67	+·01	...
				−2	−	8·64	−	8·66	+·01	+·01
				−4	−	2·74	−	2·75	...	+·01
				−6	−	·09	−	·09	...	...
	2	−1	0	4	+	·03	+	·03	...	...
				2	+	1·18	+	1·18	...	...
				0	+	9·72	+	9·72	−·01	+·01
				−2	−	2·50	−	2·52	...	+·02
				−4	+	·36	+	·36	...	...
				−6	+	·01	+	·01	...	...
ee'^2	1	2	0	2	−	·01	−	·01	...	...
				0	−	1·17	−	1·18	...	+·01
				−2	−	7·43	−	7·44	+·02	−·01
				−4	−	·31	−	·31	...	...
				−6	−	·01		...	...	−·01
	1	−2	0	4	+	·02	+	·02	...	...
				2	+	·76	+	·76	...	...
				0	+	2·59	+	2·59	−·01	+·01
				−2	+	2·54	+	2·54	−·01	+·01
				−4	+	·02	+	·02	...	...
e'^3	0	3	0	0	−	·10	−	·08	...	−·02
				−2	−	·35	−	·34	...	−·01
				−4	−	·01	−	·01	...	...
$e\gamma^2$	1	0	2	4	−	·02	−	·02	...	...
				2	−	·99	−	·99	...	...
				0	−	45·10	−	45·09	+·01	−·02
				−2	−	·18	−	·18	...	...
				−4	−	·30	−	·22	...	−·08
	1	0	−2	4	−	·07	−	·03	...	−·04
				2	−	6·3	−	6·36	...	−·02
				0	+	39·53	+	39·58	−·01	−·04
				−2	+	9·37	+	9·37	...	...
				−4	+	·20	+	·20	...	...

Prof. Brown, Final Values of Coefficients

True Longitude—Mean Longitude. Coefficients of Sine

l.	*l'.*	F.	D.		B.		H.	R.
0	1	2	2	+	″·07	+	·06	...
			0	+	·42	+	·42	...
			−2	−	2·16	−	2·15	...
			−4	−	·01	−	·04	...
0	1	−2	4		·00	−	·02	...
			2	−	1·44	−	1·55	...
			0	+	·08	+	·08	...
			−2	+	·38	+	·38	...
			−4	+	·01	+	·01	...
2	0	0	1	−	·58	−	·59	...
			−1	+	1·75	+	1·78	−·01
			−3	+	1·22	+	1·22	−·01
			−5	+	·06	+	·06	...
1	1	0	3	+	·02	+	·02	...
			1	+	1·27	+	1·27	−·01
			−1	+	·14	+	·17	...
			−3	+	·23	+	·23	...

True Longitude—Mean Longitude. Coefficients of Sines.

a.	l.	l'.	F.	D.		B.		H.	R.	B−(H+R).
$e^2e'^2$	2	2	0	0	−	″·07	−	·06	...	−·01
				−2	−	·30	−	·28	...	−·02
				−4	−	·16	−	·16	...	...
				−6	−	·01		...	...	−·01
	2	−2	0	2	+	·06	+	·06	...	...
				0	+	·20	+	·19	...	+·01
				−2	+	·26	+	·23	...	+·03
				−4	+	·04	+	·03	...	+·01
ee'^3	1	3	0	0	−	·02	−	·02	...	...
				−2	−	·25	−	·26	...	+·01
				−4	−	·02	−	·02	...	...
	1	−3	0	2	+	·03	+	·03	...	...
				0	+	·05	+	·05	...	...
e'^4	0	4	0	−2	−	·01		...	...	−·01
$e^2\gamma^2$	2	0	2	2	−	·12	−	·12	...	...
				0	−	4·00	−	4·00	...	...
				−2	+	·56	+	·56	...	...
				−4	−	·01		...	...	−·01
	2	0	−2	4	−	·01	−	·01	...	...
				2	−	·46	−	·43	...	−·03
				0	−	1·30	−	1·09	...	−·21 (c)
				−2	+	·54	+	·54	...	...
				−4	+	·17	+	·17	...	...
				−6	+	·01		...	...	+·01
$ee'\gamma^2$	1		2	2	+	·01	+	·02	...	−·01
				0	+	·26	+	·27	...	−·01
				−2	+	·06	+	·06	...	...
				−4	−	·02	−	·03	...	+·01
	1	1	−2	2	+	·08	+	·08	...	...
				0	−	·08	−	·08	...	...
				−2	+	·43	+	·43	...	...
				−4	+	·02	+	·02	...	...
	1	−1	2	2	−	·06	−	·08	...	+·02
				0	−	·30	−	·30	...	...
				−2		·00	+	·01	...	−·01
				−4	+	·02	+	·03	...	−·01
	1	−1	−2	4	−	·01		...	...	−·01
				2	−	·37	−	·40	...	+·03
				0	+	·08	+	·09	...	−·01
				−2	−	·07	−	·07	...	...
										x 2

True Longitude—Mean Longitude. Coefficients of Sines.

	l.	l'.	F.	D.		B.		H.	R.
²	0	2	2	−2	−	″·07	−	·07	...
	0	2	−2	2	−	·03	−	·01	...
				0		·00	...		...
				−2	+	·02	+	·02	...
	0	0	4	2	+	·01	+	·01	...
				0	+	·42	+	·42	...
				−2	+	·07	+	·08	...
a	3	0	0	1	−	·04	−	·04	...
				−1	+	·13	+	·12	...
				−3	+	·05	+	·06	...
				−5	+	·02	...		...
'a	2	1	0	1	+	·09	+	·09	...
				−1	+	·01	+	·01	...
				−3	+	·08	+	·08	...
				−5	+	·01	+	·01	...
	2	−1	0	1	−	·01	−	·02	...

True Longitude—Mean Longitude. Coefficients of Sines.

O.	l.	l'.	F.	D.	B.	H.	R.	B−(H+R).
e^4e'	4	1	0	0	−″·04	−·04	...	...
				−2	−·03	−·03	...	...
	4	−1	0	2	+·01	...	...	+·01
				0	+·05	+·05	...	...
				−2	−·02	−·02	...	...
$e^3e'^2$	3	2	0	−2	−·02	−·02	...	...
				−4	−·01	...	...	−·01
	3	−2	0	2	+·01	...	...	+·01
				0	+·02	+·01	...	+·01
				−2	+·01	+·01	...	...
$e^2e'^3$	2	3	0	−2	−·01	−·01	...	...
				−4	−·01	...	...	−·01
$e^3\gamma^2$	3	0	2	2	−·01	−·01	...	...
				0	−·33	−·33	...	...
				−2	+·09	+·10	...	−·01
	3	0	−2	2	−·03	−·03	...	...
				0	−·06	−·07	...	+·01
				−2	−·01	−·01	...	...
				−4	+·01	+·01	...	...
$e^2e'\gamma^2$	2	1	2	0	+·04	+·04	...	...
				−2	+·03	+·03	...	...
	2	1	−2	2	+·01	+·01	...	...
				0	+·03	−·07	...	+·10
				−2	+·02	+·02	...	...
				−4	+·02	+·01	...	+·01
	2	−1	2	2	−·01	−·01	...	...
				0	−·05	−·05	...	...
				−2	·00	+·01	...	−·01
	2	−1	−2	2	−·03	−·03	...	...
				0	−·02	−·01	...	−·01
$ee'^2\gamma^2$	1	2	2	−2	·00	+·01	...	−·01
	1	2	−2	−2	+·02	+·02	...	...
	1	−2	2	0	−·01	...	...	−·01
				−2	+·01	...	...	+·01
	1	−2	−2	2	−·02	+·01	...	−·03
				0	·00	...	...	...
				−2	−·01	...	...	−·01

True Longitude—Mean Longitude. Coefficients of Sines.

.	l.	l'.	F.	D.	B.	H.	R.	B−
γ^4	1	0	4	0	+ ″·09	+ ·09	...	
				−2	+ ·01	+ ·01	...	
	1	0	−4	2	·00	+ ·03	...	−
				0	− ·08	− ·08	...	
				−2	− ·02	− ·02	...	
a	4	0	0	−1	+ ·01	+ ·01	...	
$'a$	3	1	0	1	+ ·01	+ ·01	...	
	3	−1	0	−1	− ·02	− ·02	...	
.				−3	+ ·01	...	...	+
^2a	2	0	2	1	+ ·01	...	...	+
	2	0	−2	1	·00	− ·01	...	+
γ^2a	1	1	2	1	− ·01	− ·01	...	
	1	1	−2	1	·00	− ·05	...	+
6	6	0	0	0	+ ·01	+ ·01	...	
γ^2	4	0	2	0	− ·03	− ·03	...	
				−2	+ ·01	+ ·01	...	

Latitude. Coefficients of Sines.

a.	l.	l'.	F.	D.		B.		H.	R.	B−(H+R).
π'	0	1	1	4	−	·02	−	·03	...	+·01
				2	−	1·27	−	1·28	...	+·01
				0	−	6·49	−	6·50	+ ·01	...
				−2	−	29·69	−	29·74	+ ·04	+·01
				−4	−	·42	−	·41	...	−·01
				−6	−	·01		...	...	−·01
	0	−1	1	4	+	·15	+	·16	...	−·01
				2	+	8·00	+	8·00	− ·01	+·01
				0	+	4·86	+	4·88	− ·01	−·01
				−2	+	12·14	+	12·14	− ·01	+·01
				−4	+	·11	+	·10	...	+·01
a	0	0	1	3	−	·03	−	·03	...	...
				1	−	5·36	−	5·25	+ ·04	−·15
				−1	+	4·80	+	4·69	− ·04	+·15
				−3	+	·35	+	·35	...	...
	0	0	3	2	−	·14	−	·15	...	+·01
				0	−	6·30	−	6·30	...	...
				−2	−	2·19	−	2·19	...	...
				−4	−	·06	−	·07	...	+·01
	2	0	1	4	+	·03	+	·03	...	...
				2	+	1·52	+	1·52	...	...
				0	+	61·91	+	61·90	−·01	+·02
				−2	−	15·57	−	15·56	...	−·01
				−4	−	·64	−	·63	...	−·01
				−6	−	·08	−	·07	...	−·01
	−2	0	1	6	+	·06	+	·06	...	...
				4	+	2·41	+	2·42	...	−·01
				2	−	1·62	−	1·62	...	...
				0	−	31·76	−	31·77	...	+·01
				−2	−	2·15	−	2·15	...	...
				−4	−	·05	−	·05	...	...
	1	1	1	4	−	·01	−	·01	...	...
				2	−	·24	−	·24	...	...
				0	−	5·33	−	5·34	+·01	...
				−2	−	7·46	−	7·48	+·01	+·01
				−4	−	·60	−	·52	...	−·08
				−6	−	·02		·00	...	−·02

Latitude. Coefficients of Sines.

l.	l'.	F.	D.	B.	H.	R.	B
−1	−1	1	6	+ ·01	+ ·01	...	
			4	+ ·34	+ ·35	...	
			2	+ 8·90	+ 8·91	−·01	
			0	+ 5·10	+ 5·13	−·01	
			−2	+ ·83	+ ·83	...	
			−4	+ ·02	+ ·01	...	
1	−1	1	4	+ ·03	+ ·03	...	
			2	+ 1·14	+ 1·14	...	
			0	+ 6·76	+ 6·76	−·01	
			−2	+ ·80	+ ·80	...	
			−4	+ ·17	+ ·15	...	
−1	1	1	4	− ·05	− ·06	...	
			2	− 1·32	− 1·32	...	
			0	− 5·66	− 5·67	+ ·01	
			−2	− 1·77	− 1·78	...	
			−4	− ·06	− ·05	...	

Latitude. Coefficients of Sines.

Cl.	l.	l'.	F.	D.	B.	H.	R.	B−(H+R).
γ^3	1	0	3	2	− ·03	− ·03	...	...
				0	− 1·02	− 1·02	...	...
				−2	− ·33	− ·33	...	...
				−4	+ ·01	+ ·02	...	− ·01
	−1	0	3	4	− ·01	− ·01	...	...
				2	− ·24	− ·25	...	+ ·01
				0	− 2·81	− 2·81	...	...
				−2	+ ·29	+ ·29	...	...
				−4	+ ·01	·00	...	+ ·01
$\gamma^3 e'$	0	1	3	0	+ ·01	+ ·01	...	...
				−2	− ·09	− ·09	...	...
				−4	− ·01	·00	...	− ·01
	0	−1	3	2	− ·01	− ·01	...	...
				0	·00	·00	...	...
				−2	+ ·06	+ ·07	...	− ·01
γe^3	3	0	1	2	+ ·14	+ ·14	...	...
				0	+ 3·98	+ 3·98	...	...
				−2	− 1·52	− 1·52	...	...
				−4	+ ·01	·00	...	+ ·01
				−6	− ·01	·00	...	− ·01
	−3	0	1	6	+ ·03	+ ·03	...	...
				4	+ ·02	+ ·02	...	...
				2	+ ·26	+ ·27	...	− ·01
				0	− 1·59	− 1·59	...	...
				−2	− ·15	− ·15	...	...
$\gamma e^2 e'$	2	1	1	2	− ·03	− ·03	...	...
				0	− ·64	− ·64	...	...
				−2	− ·66	− ·66	...	...
				−4	− ·05	− ·03	...	− ·02
				−6	− ·01	...	...	− ·01
	−2	−1	1	6	+ ·01	+ ·01	...	...
				4	+ ·22	+ ·22	...	...
				2	− ·06	− ·06	...	...
				0	+ ·31	+ ·31	...	...
				−2	+ ·06	+ ·06	...	...
	2	−1	1	2	+ ·11	+ ·13	...	− ·02
				0	+ ·81	+ ·80	...	+ ·01
				−2	− ·08	− ·09	...	+ ·01
	−2	1	1	4	− ·03	− ·03	...	...
				2	+ ·06	+ ·06	...	...
				0	− ·30	− ·31	...	+ ·01
				−2	− ·13	− ·12	...	− ·01
				−4	− ·01	...	...	− ·01

Latitude. Coefficients of Sines.

l.	l'.	F.	D.	B.	H.	R.	B−(
1	2	1	0	− ·06	− ·06	...	
			−2	− ·27	− ·28	...	+
			−4	− ·03	− ·03	...	
−1	−2	1	4	+ ·02	+ ·02	...	
			2	+ ·32	+ ·32	...	
			0	+ ·06	+ ·06	...	
			−2	+ ·01	+ ·01	...	
1	−2	1	2	+ ·05	+ ·06	...	−
			0	+ ·12	+ ·12	...	
			−2	+ ·11	+ ·10	...	+
−1	2	1	2	− ·12	− ·12	...	
			0	− ·10	− ·11	...	+
			−2	− ·07	− ·06	...	−
0	3	1	−2	− ·04	− ·01	...	−
0	−3	1	2	+ ·01	+ ·02	...	−
0	0	3	1	+ ·01	+ ·01	...	

Latitude. Coefficients of Sines.

a.	l.	l'.	F.	D.		B.		H.	R.	B−(H+R).
γ^3e^2	2	0	3	0	−	·12	−	·12	...	...
				−2	−	·02	−	·02	...	...
				−4	+	·01	+	·01	...	...
	·2	0	3	4	−	·01	−	·01	...	...
				2	−	·07	−	·07	...	...
				0	+	·13	+	·11	...	+·02
				−2	+	·01	+	·01	...	...
γ^3ee'	1	1	3	0	+	·01	+	·01	...	...
				−2	−	·01	−	·01	...	...
	−1	−1	3	2	−	·01	−	·01	...	...
				0	+	·01		·00	...	+·01
				−2	−	·01	−	·01	...	...
	1	−1	3	0	−	·01	−	·01	...	...
	−1	1	3	0	−	·01	−	·01	...	...
				−2	+	·02	+	·03	...	−·01
γe^4	4	0	1	2	+	·01	+	·01	...	...
				0	+	·27	+	·26	...	+·01
				−2	−	·14	−	13	...	−·01
				−4	+	·01	+	·01	...	...
	−4	0	1	2	+	·03	+	·03	...	...
				0	−	·09	−	·09	...	...
				−2	−	·01	−	·01	...	...
e^3e'	3	1	1	0	−	·06	−	·06	...	...
				−2	−	·06	−	·06	...	...
				−4		·00	+	·01	...	−·01
	−3	−1	1	2	+	·01	+	·01	...	...
				0	+	·02	+	·03	...	−·01
				−2	+	·01		...	...	+·01
	3	−1	1	2	+	·01	+	·01	...	...
				0	+	·08	+	·08	...	...
				−2	−	·02	−	·03	...	+·01
	−3	1	1	4		·00	+	·01	...	−·01
				0	−	·02	−	·02	...	...
				−2	−	·01		...	...	−·01
$\gamma e^2e'^2$	2	2	1	0	−	·01	−	·01	...	...
				−2	−	·02	−	·03	...	+·01
	−2	−2	1	4	+	·01	+	·01	...	...
	2	−2	1	2	+	·01	+	·01	...	...
				0	+	·02	+	·02	...	...
				−2	+	·01	+	·02	...	−·01
	−2	2	1	2	−	·01	−	·01	...	...
				0	−	·01		·00	...	−·01
				−2	−	·01		...	...	−·01

Latitude. Coefficients of Sines.

l.	*l'.*	F.	D.	B.		H.		R.	B
1	3	1	−2	−	·01	−	·01	...	
−1	−3	1	2	+	·01	+	·01	...	
3	0	1	1	−	·01	−	·01	...	
			−1	+	·01	+	·02	...	
−3	0	1	1	−	·01	...		...	
2	1	1	1	+	·01	+	·01	...	
2	−1	1	−1	−	·02	−	·02	...	
−2	1	1	1	+	·02	+	·02	...	
3	0	3	0	−	·01	−	·01	...	
−3	0	3	0		·00	+	·01	...	
5	0	1	0	+	·02	+	·02	...	
			−2	−	·01	−	·01	...	
−5	0	1	0	−	·01	−	·01	...	
4	−1	1	0	Not cal.		+	·01	...	
4	1	1	−2	"		−	·01	...	

Sine Parallax. Coefficients of Cosines.

l.	*l'.*	F.	D.	B.	H.	R.	B

Sine Parallax. Coefficients of Cosines.

O.	l.	l'.	F.	D.	B.	H.	R.	B−(H+R).
ee'	1	1	0	4	−·001	...	...	−·001
				2	−·049	−·049	...	...
				0	−·950	−·961	+·001	+·010
				−2	+1·446	+1·447	−·002	+·001
				−4	+·067	+·069	...	−·002
				−6	+·002	+·001	...	+·001
	1	−1	0	4	+·006	+·007	...	−·001
				2	+·231	+·229	...	+·002
				0	+1·154	+1·144	−·001	+·011
				−2	−·226	−·227	...	+·001
				−4	−·010	−·009	...	−·001
				−6	−·001	...	...	−·001
e'^2	0	2	0	2	−·003	−·002	...	−·001
				0	−·009	−·008	...	−·001
				−2	+·092	+·092	...	...
				−4	+·003	+·002	...	+·001
[illegible]	0	0	2	2	−·001	−·001	...	...
				0	−·012	−·012	...	...
				−2	−·105	−·105	...	...
				−4	+·003	+·002	...	+·001
[illegible]	1	0	0	1	−·109	−·106	+·001	−·004
				−1	+·012	+·011	...	+·001
				−3	−·039	−·037	...	−·002
$e'a$	0	1	0	3	+·003	+·002	...	+·001
				1	+·149	+·146	−·001	+·004
				−1	−·004	−·004	...	...
				−3	+·001	+·001	...	...
e^3	3	0	0	4	+·001	...	...	+·001
				2	+·024	+·023	...	+·001
				0	+·622	+·620	...	+·002
				−2	−·119	−·121	...	+·002
				−4	+·007	+·008	...	−·001
				−6	+·005	+·004	...	+·001
e^2e'	2	1	0	2	−·005	−·004	...	−·001
				0	−·104	−·122	...	+·018
				−2	−·019	−·019	...	...
				−4	+·032	+·032	...	...
				−6	+·002	+·001	...	+·001
	2	−1	0	4	+·001	...	...	+·001
				2	+·021	+·022	...	−·001
				0	+·127	+·149	...	−·022
				−2	−·002	−·002	...	...
				−4	−·004	−·004	...	...

Sine Parallax. Coefficients of Cosines.

l.	*l'.*	F.	D.		B.		H.	R.
1	2	0	0	−	·011	−	·010	...
			−2	+	049	+	·049	...
			−4	+	·004	+	·004	...
1	−2	0	4	+	·001		...	...
			2	+	·011	+	·012	...
			0	+	·020	+	·012	...
			−2	−	·021	−	·021	...
0	3	0	−2	+	004	+	·004	...
1	0	2	0	−	·001		·000	...
			−2	−	·083	−	·083	...
			−4	+	·001	+	·001	...
1	0	−2	4	−	·001		...	...
			2	−	·048	−	·048	...
			0	−	·714	−	·709	...
			−2	−	·011	−	·011	...
0	1	2	0	+	001	+	·001	...
			−2	−	·007	−	·007	...

Sine Parallax. Coefficients of Cosines.

O.	l.	l'.	F.	D.		B.		H.	R.	B−(H+R).
$e^2e'^2$	2	2	0	0	−	·001		...	...	−·001
				−2	−	·001	−	·001	...	...
				−4	+	·002	+	·002	...	...
	2	−2	0	2	+	·001	+	·001	...	...
				0	+	·002	+	·001	...	+·001
				−2		·000	+	·001	...	−·001
				−4	−	·001		·000	...	−·001
ee'^3	1	3	0	−2	+	·001	+	·001	...	...
$e^2\gamma^2$	2	0	2	−2	−	·009	−	·009	...	...
	2	0	−2	2	−	·005	−	·004	...	−·001
				0		·000		·000	...	...
				−2	−	·014	−	·014	...	...
$ee'\gamma^2$	1	1	2	−2	−	·003	−	·002	...	−·001
	1	1	−2	2	+	·001	+	·000	...	+·001
				0	+	·002	+	·002	...	...
				−2	−	·001		...	...	−·001
	1	−1	2	−2		·000	+	·001	...	−·001
	1	−1	−2	2	−	·003	−	·003	...	...
				0	−	·003	−	·003	...	...
e^3a	3	0	0	1	−	·001	−	·001	...	...
				−1	+	·002	+	·001	...	+·001
$e^2e'a$	2	1	0	1	+	·002	+	·001	...	+·001
				−1		·000		...	...	...
				−3	−	·001		...	...	−·001
	2	−1	0	1	−	·001		...	...	−·001
				−1	−	·003	−	·003	...	...
				−3	−	·001		...	...	−·001
ek^2a	1	0	2	−1	+	·001		...	...	+·001
	1	0	−2	−1	+	·001		...	...	+·001
e^5	5	0	0	0	+	·003	+	·003	...	...
				−2	−	·001	−	·002	...	+·001
e^4e'	4	1	0	0	Not cal.		−	·001	...	...
				−2	„		−	·001	...	...
	4	−1	0	0	„		+	·001	...	...
e^3k^2	3	0	2	−2	−	·001	−	·001	...	...
	3	0	−2	2	−	·001		...	...	−·001
				−4	−	·001		...	...	−·001

[redacted] *cript added* 1905 *January* 25.—The coefficients resulting
[redacted] theory are given above to hundredths of a second in
[redacted] e and latitude, and to thousandths of a second in parallax.
[redacted] case they have actually been calculated to one more place
[redacted] als. Further, the coefficients, referred to rectangular
[redacted] tes, have been found with even greater accuracy in the
[redacted] jority of cases. The final results with the full number
[redacted] of decimals used are probably correct within two units
[redacted] st figure given, as far as the terms in any one character-
[redacted] concerned ; they will be found in the fourth part of the
[redacted] of the Motion of the Moon," shortly to appear in the
[redacted] of the Society.

[redacted] coefficients are all definitive with the exception of two or
[redacted] hich require small corrections not exceeding 0″·02, due to
[redacted] terms of the disturbing function which have been
[redacted] d. See *Mem. R.A.S.* vol. liii. p. 50.

[redacted] *ford College:*
[redacted] 4 *November* 15.

Observations of Occultations of Stars by the Moon made at the Royal Observatory, Greenwich, in the year 1904.

(Communicated by the Astronomer-Royal.)

Day.		Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
	1904.						h m s	
Jan.	26 (*a*) (*b*)	Disapp.	W. B. II. 1033	Astrographic Equatorial	225	Dark	7 18 29·76	H.
	26 (*b*)	,,	,,	Thompson Equatorial	110	,,	7 18 30·25	C. D.
	26 (*b*)	,,	,,	Great Equatorial	670	,,	7 18 30·40	W. B.
	26 (*b*)	,,	,,	Merz Refractor	250	,,	7 18 29·85	P. M.
Mar.	21 (*c*)	,,	W. B. III. 474	Astrographic Equatorial	225	,,	9 33 53·47	W. S.
	22 (*d*) (*e*)	,,	θ^1 Tauri	,, ,,	225	,,	9 59 34·22	H.
	22 (*d*)	,,	,,	Sheepshanks Equatorial	100	,,	9 59 34·36	W.
	22 (*d*) (*e*)	,,	75 Tauri	Astrographic Equatorial	225	,,	10 2 51·87	H.
	22 (*d*)	,,	,,	Sheepshanks Equatorial	100	,,	10 2 52·21	W.
	22 (*d*) (*e*)	,,	W. B. (2) IV. 450	Astrographic Equatorial	225	,,	10 3 38·24	H.
	22 (*d*)	,,	,,	Sheepshanks Equatorial	100	,,	10 3 37·28	W.
	27	,,	W. B. IX. 127	Astrographic Equatorial	225	,,	8 17 5·54	W. S.
	27 (*c*)	,,	Piazzi IX. 35	,, ,,	225	,,	9 47 22·37	W. S.
Apr.	19	,,	B. D. + 16°, 701	,, ,,	225	,,	8 33 40·79	W. S.
	19	,,	Lalande 9625	,, ,,	225	,,	8 34 52·59	W. S.
	21	,,	B. D. + 17°, 1488	,, ,,	225	,,	9 36 51·28	W. S.
	21	,,	B. D. + 16°, 1373	,, ,,	225	,,	9 41 4·59	W. S.
	21	,,	W. B. (2) IV. 1723–4	,, ,,	225	,,	9 57 30·89	W. S.

ett)	120	"	9 24 2·01	V.
	120	"	14 56 12·45	D.
l	225	"	14 57 50·72	H.
l	100	"	14 57 50·30	A. C.
ett)	120	Bright	14 59 (59·33)	D.
l	225	"	15 0 1·17	H.
	670	"	15 0 1·13	W. B.
ett)	120	"	17 31 2·43	D.
l	225	"	17 31 2·27	H.
l	100	"	17 31 3·07	A. C.
	670	"	17 31 2·53	W. B.
ett)	120	Dark	18 24 27·06	D.
	670	"	18 24 26·76	W. B.
l	100	"	11 15 (51·32)	V.
	670	"	11 15 (48·63)	J.
l	100	"	16 12 37·94	W.
	250	"	11 29 34·77	C. D.
l	225	Bright	9 16 47·42	W.
l	100	Dark	10 2 19·60	H. F.

Day.	Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1904. Sept. 29 (*a*)	Reapp.	γ Tauri	Astrographic Equatorial	225	Dark	10 2 20·21	W.
29	Disapp.	71 Tauri	Great Equatorial	670	Bright	12 33 33·86	D.
29 (*e*)	"	"	Astrographic Equatorial	225	"	12 33 (30·93)	H.
29 (*g*) (*j*)	"	"	Merz Refractor	250	"	12 33 32·61	C. D.
29	"	"	Thompson Equatorial	110	"	12 33 (36·11)	R. F.
29	Reapp.	"	Great Equatorial	670	Dark	13 7 41·30	D.
29 (*a*)	"	"	Astrographic Equatorial	225	"	13 7 40·66	H.
29	"	"	Merz Refractor	250	"	13 7 40·97	C. D.
29	"	"	Sheepshanks Equatorial	100	"	13 7 40·68	W.
29	"	"	Thompson Equatorial	110	"	13 7 41·17	R. F.
29 (*i*)	Disapp.	θ^1 Tauri	Great Equatorial	670	Bright	13 40 2·64	D.
29 (*e*) (*c*)	"	"	Astrographic Equatorial	225	"	13 39 (58·99)	H.
29 (*g*)	"	"	Merz Refractor	250	"	13 40 4·12	C. D.
29 (*g*)	"	"	Sheepshanks Equatorial	100	"	13 39 (59·60)	W
29	"	"	Thompson Equatorial	110	"	13 39 (56·82)	R. F.
29	"	θ^2 Tauri	Great Equatorial	670	"	13 43 48·70	D.
29 (*e*)	"	"	Astrographic Equatorial	225	"	13 43 47·56	H.
29	"	"	Merz Refractor	250	"	13 43 48·49	C. D.
29	"	"	Sheepshanks Equatorial	100	"	13 43 47·48	W.
29	"	"	Thompson Equatorial	110	"	13 43 45·99	R. F.

	670	Bright	14 8 20·44	D.
ial	225	„	14 8 (10·86)	H.
	670	Dark	14 53 51·40	D.
ial	225	„	14 53 51·24	H.
	250	„	14 53 51·12	C. D.
al	100	„	14 53 51·74	W.
	110	„	14 53 50·72	R. F.
	670	„	14 57 44·06	D.
ial	225	„	14 57 44·71	H.
	250	„	14 57 43·98	C. D.
al	100	„	14 57 44·42	W.
	110	„	14 57 44·18	R. F.
	670	Bright	15 1 8·99	D.
ial	225	„	15 1 (5·75)	H.
	250	„	15 1 8·71	C. D.
al	100	„	15 1 8·35	W.
	670	Dark	15 12 (29·34)	D.
	250	„	15 12 (17·37)	C. D.
al	100	„	15 12 (23·13)	W.
	110	„	15 12 (17·37)	R. F.

Day.		Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1904. Nov.	20	Disapp.	64 Ceti	Sheepshanks Equatorial	100	Dark	9 12 33·97	J. S.
	20	„	„	Astrographic Equatorial	225	„	9 12 33·79	W. S.
	20	„	ξ^1 Ceti	Sheepshanks Equatorial	100	„	10 23 26·54	J. S.
	20	„	„	Astrographic Equatorial	225	„	10 23 26·35	W. S.
Dec.	20	„	γ Tauri	Great Equatorial (Corbett)	120	„	6 0 50·10	D.
	20 (*a*)	„	„	Astrographic Equatorial	225	„	6 0 50·12	H.
	20	„	„	Merz Refractor	250	„	6 0 50·03	C. D.
	20	„	„	Great Equatorial	670	„	6 0 50·30	W. B.
	20	„	„	Sheepshanks Equatorial	100	„	6 0 50·00	H. F.
	20	Reapp.	„	Great Equatorial	670	Bright	7 4 37·61	W. B.
	20	Disapp.	70 Tauri	Thompson Equatorial	110	Dark	9 19 26·16	C. D.
	20	„	„	Great Equatorial	670	„	9 19 26·58	W. B.
	20	„	75 Tauri	„ (Corbett)	120	„	11 16 0·52	D.
	20	„	„	Astrographic Equatorial	225	„	11 16 1·10	H.
	20	„	„	Merz Refractor	250	„	11 16 0·77	C. D.
	20	„	„	Great Equatorial	670	„	11 16 0·52	W. B.
	20	„	„	Thompson Equatorial	110	„	11 16 0·37	R. F.
	20	„	„	Old Altazimuth	100	„	11 16 1·29	V.
	20	„	W. B. (2) IV. 450	Great Equatorial (Corbett)	120	„	11 23 13·34	D.
	20	„	„	Astrographic Equatorial	225	„	11 23 13·22	H.

			Observation. h m s	
	250	Dark	11 23 13·78	C. D.
	670	"	11 23 13·44	W. B.
al	225	"	11 24 38·89	H.
	250	"	11 24 39·65	C. D.
	670	"	11 24 39·41	W. B.
l	100	"	11 24 38·52	H. F.
	100	"	11 24(31·37)	V.
	670	Bright	11 57 48·66	D
	670	Dark	12 20 15·47	D.
al	225	"	12 20 15·97	H.
	250	"	12 20 15·90	C. D.
ett)	120	"	12 20 15·97	W. B.
l	100	"	12 20 15·68	R. C.
ett)	120	"	15 18 26·50	D.
l	225	"	15 18 26·43	H.
	250	"	15 18 26·38	C. D.
	670	"	15 18 26·60	W. B.

Notes.

(*a*) Instantaneous. (*b*) Unsteady, cloudy. (*c*) Very faint. (*d*) Diffused. (*e*) Not quite instantaneous.
(*f*) The star appeared to glide up to and under the limb. (*g*) Observation doubtful. (*h*) Definition not good.
(*i*) The star was projected on the limb of the Moon. (*j*) The limb was boiling.
(*k*) This phenomenon was very near the bright limb of the Moon.
(*l*) The times of observation differ so widely that no reliable mean can be adopted.

The apertures of the telescopes used are as follows :—

	inches.		inches.
Great Equatorial	28	Sheepshanks Equatorial	6¾
Thompson Equatorial	26	Great Equatorial (Corbett Telescope)	6⅓
Merz Refractor	12¾	Old Altazimuth	4
Astrographic Equatorial (Guiding Telescope) ...	10		

The initials D., H., A. C., C. D., W. B., H. F., W., J. S., P. M., W. S., E., R. C., R. F., V., J., are those of Mr. Dyson, Mr. Hollis, Mr. Crommelin, Mr. Davidson, Mr. Bowyer, Mr. Furner, Mr. Witchell, Mr. Storey, Mr. Melotte, Mr. Stevens, Mr. J. Evans, Mr. Cullen, Mr. Fowler, Mr. Vagg, and Mr. James respectively.

It may be pointed out that the *Nautical Almanac* predictions for the star θ^2 *Tauri* are erroneous throughout the year. The R.A. and Dec. of this star, as given in the *Nautical Almanac* for 1904, are too great by $10^s.18$, $25''.3$ respectively.

Royal Observatory, Greenwich:
1905 *January* 13.

Ephemeris for Physical Observations

P.	L – O.	B.	Equat. Diam.	Excess over Polar.	Defect of Illum.	Q.	d.
°	°	°	"	"	"	°	°
344·35	275·81	+2·97	33·94	2·19	0·06	253·06	5·06
344·75	276·93	2·98	34·14	2·20	·08	253·67	5·72
345·14	278·02	2·99	34·36	2·21	·10	254·25	6·36
345·54	279·09	3·00	34·61	2·23	·13	254·77	6·98
345·93	280·14	3·01	34·90	2·25	·15	255·27	7·58
346·32	281·17	3·02	35·21	2·27	·18	255·75	8·15
346·69	282·17	3·03	35·54	2·29	·20	256·21	8·69
347·05	283·12	3·04	35·91	2·31	·23	256·64	9·19
347·41	284·03	3·04	36·31	2·34	·25	257·05	9·66
347·75	284·90	3·05	36·74	2·37	·28	257·45	10·08
348·09	285·74	3·06	37·19	2·40	·31	257·83	10·46
348·41	286·53	3·06	37·67	2·43	·33	258·19	10·79
348·71	287·26	3·07	38·18	2·46	·35	258·53	11·08
348·99	287·94	3·08	38·72	2·49	·37	258·86	11·31

of Jupiter, 1905–6. By A. C. D. Crommelin.

Greenwich Mean Noon. 1905.	Light Time.	Longitude of Central Meridian. I. 877°·90.	II. 870°·27.	Corr. for Phase.	A–O.	B.
	m	°	°	°	°	°
June 8	48·945	296·85	293·56	+0·11	270·75	+3·07
13	48·663	5·40	323·96	·14	271·21	3·07
18	48·345	74·00	354·41	·18	271·66	3·07
23	47·993	142·64	24·90	·21	272·11	3·07
28	47·606	211·33	55·44	·25	272·56	3·07
July 3	47·186	280·05	86·01	·29	273·02	3·06
8	46·737	348·83	116·63	·33	273·48	3·06
13	46·259	57·67	147·32	·37	273·93	3·06
18	45·753	126·57	178·07	·41	274·37	3·06
23	45·223	195·52	208·86	·44	274·82	3·06
28	44·669	264·52	239·71	·48	275·28	3·06
Aug. 2	44·096	333·58	270·62	·51	275·74	3·05
7	43·504	42·71	301·60	·54	276·18	3·05
12	42·900	111·90	332·64	·56	276·63	3·05
17	42·281	181·16	3·74	·57	277·08	3·04
22	41·656	250·48	34·91	·58	277·53	3·04
27	41·024	319·88	66·15	·59	277·98	3·04
Sept. 1	40·393	29·34	97·46	·58	278·43	3·03
6	39·762	98·88	128·85	·57	278·87	3·03
11	39·138	168·49	160·30	·56	279·32	3·03
16	38·524	238·16	191·82	·54	279·77	3·02
21	37·927	307·92	223·33	·50	280·23	3·02
26	37·349	17·74	254·89	·46	280·67	3·02
Oct. 1	36·797	87·63	286·73	·42	281·09	3·01
6	36·271	157·58	318·63	·37	281·53	3·01
11	35·783	227·61	350·50	·32	281·99	3·00
16	35·332	297·68	22·42	·27	282·44	3·00
21	34·926	7·81	54·40	·21	282·89	2·99
26	34·568	77·98	86·42	·16	283·33	2·99
31	34·263	148·18	118·46	·12	283·77	2·98
Nov. 5	34·014	218·40	150·53	·07	284·22	2·97
10	33·826	288·63	182·61	·04	284·67	2·97
15	33·698	358·85	214·68	+ ·02	285·10	2·96
20	33·634	69·06	246·74	·00	285·54	2·95
25	33·634	139·25	278·78	·00	286·00	2·95
30	33·701	209·39	310·77	+0·00	286·44	+2·94

	P.	L−O.	B.	Equat. Diam.	Excess over Polar.	Defect of Illum.	Q.
	°	°	°	″	″	″	°
	347·56	284·40	+3·12	49·10	3·16	0·02	73·50
	347·32	283·77	3·10	48·82	3·14	·05	74·71
	347·09	283·18	3·08	48·45	3·12	·08	75·28
	346·88	282·64	3·06	48·01	3·09	·11	75·59
	346·69	282·17	3·03	47·50	3·06	·15	75·73
	346·53	281·76	3·01	46·93	3·02	·19	75·79
4	346·41	281·43	2·99	46·32	2·98	·23	75·85
9	346·31	281·19	2·97	45·66	2·94	·27	75·95
14	346·25	281·02	2·94	44·99	2·90	·30	76·05
19	346·22	280·94	2·92	44·29	2·86	·33	76·16
24	346·22	280·95	2·90	43·58	2·81	·35	76·27
29	346·25	281·04	2·88	42·87	2·76	·37	76·39
. 3	346·32	281·22	2·86	42·17	2·71	·38	76·52
8	346·41	281·48	2·84	41·48	2·67	·39	76·68
13	346·54	281·81	2·82	40·79	2·63	·39	76·84
	346·70	282·23	2·80	40·12	2·58	·39	77·02
			2·79	39·48	2·54	·38	77·21
					[illegible]	·37	77·44

Greenwich Mean Noon.	Light time.	Longitude of Central Meridian. I. 877°·90.	II. 870°·27.	Corr. for Phase.	A—O.	B.
1905.	m	°	°	°	°	°
Dec. 5	33·832	279·47	342·70	−0·03	286·89	+2·94
10	34·029	349·48	14·56	·06	287·33	2·93
15	34·286	59·41	46·35	·09	287·77	2·92
20	34·602	129·25	78·04	·14	288·21	2·92
25	34·971	199·00	109·64	·18	288·65	2·91
30	35·394	268·65	141·14	·23	289·10	2·90
1906.						
Jan. 4	35·864	338·20	172·54	·29	289·54	2·89
9	36·377	47·63	203·82	·34	289·98	2·88
14	36·927	116·96	235·01	·38	290·42	2·87
19	37·508	186·18	266·08	·43	290·87	2·87
24	38·118	255·30	297·06	·47	291·31	2·86
29	38·750	324·32	327·93	·50	291·75	2·85
Feb. 3	39·399	33·25	358·71	·53	292·19	2·84
8	40·061	102·09	29·41	·54	292·63	2·83
13	40·730	170·85	60·02	·55	293·06	2·82
18	41·403	239·53	90·55	·55	293·51	2·81
23	42·074	308·13	121·01	·55	293·94	2·80
28	42·739	16·68	151·41	·54	294·39	2·79
Mar. 5	43·397	85·16	181·74	·52	294·83	2·78
10	44·042	153·59	212·02	·50	295·27	2·77
15	44·670	221·97	242·26	·47	295·70	2·76
20	45·280	290·31	272·45	·44	296·14	2·75
25	45·868	358·62	302·61	·41	296·58	2·74
30	46·432	66·90	332·75	·37	297·01	2·73
Apr. 4	46·969	135·16	2·86	·33	297·45	2·72
9	47·477	203·40	32·95	·29	297·89	2·71
14	47·953	271·62	63·02	·26	298·33	2·70
19	48·397	339·83	93·09	·22	298·76	2·69
24	48·807	48·04	123·15	·18	299·21	2·67
29	49·181	116·24	153·21	·16	299·65	2·66
May 4	49·518	184·45	183·27	−0·12	300·08	2·65
July 15	49·922	16·65	186·10	+0·10	306·32	2·47
20	49·640	85·24	216·54	·13	306·75	2·46
25	49·322	153·86	247·02	·17	307·18	2·44
30	48·968	222·53	277·54	·20	307·62	2·43
Aug. 4	48·580	291·25	308·10	·24	308·05	2·42
9	48·160	0·03	338·72	+·28	308·48	+2·40

P.	L−O.	B.	Equat. Diam.	Excess over Polar.	Defect of Illum.	Q.	d.
°	°	°	"	"	"	°	°
2·20	317·36	+2·23	34·82	2·24	0·19	270·93	8·45
2·62	318·28	2·21	35·18	2·26	·22	271·39	8·94
3·03	319·16	2·19	35·56	2·29	·24	271·82	9·39
3·42	320·00	2·17	35·98	2·31	·26	272·22	9·81
3·79	320·80	2·15	36·42	2·34	·28	272·59	10·17
4·14	321·55	2·13	36·89	2·37	·30	272·93	10·49
4·46	322·24	2·11	37·38	2·41	·33	273·25	10·76
4·75	322·88	2·09	37·90	2·44	·35	273·54	10·98
5·02	323·47	2·08	38·45	2·48	·36	273·80	11·13
5·25	323·98	2·06	39·02	2·51	·37	274·04	11·22
5·46	324·43	2·04	39·61	2·55	·38	274·25	11·24
5·63	324·81	2·03	40·23	2·59	·38	274·44	11·19
5·77	325·12	2·02	40·86	2·63	·38	274·60	11·08
5·87	325·35	2·01	41·50	2·67	·37	274·72	10·88
5·94	325·50	2·00	42·14	2·71	·36	274·82	10·60
5·97	325·56	1·99	42·79	2·75	·34	274·86	10·24

Greenwich Mean Noon.	Light time.	Longitude of Central Meridian. I. 877°·90.	II. 870°·27.	Corr. for Phase.	A—O.	B.
1906.	m	°	°	°	°	°
Aug. 14	47·708	68·85	9·39	+0·31	308·91	+2·39
19	47·225	137·72	40·11	·35	309·34	2·37
24	46·715	206·65	70·89	·38	309·77	2·36
29	46·178	275·64	101·72	·42	310·19	2·34
Sept. 3	45·619	344·68	132·61	·45	310·63	2·33
8	45·040	53·79	163·57	·48	311·06	2·31
13	44·442	122·96	194·59	·50	311·49	2·30
18	43·829	192·18	225·66	·53	311·91	2·28
23	43·203	261·48	256·80	·54	312·34	2·27
28	42·570	330·85	288·02	·55	312·76	2·25
Oct. 3	41·932	40·30	319·31	·55	313·19	2·24
8	41·294	109·80	350·66	·55	313·62	2·22
13	40·660	179·38	22·09	·54	314·05	2·20
18	40·034	249·03	53·59	·52	314·47	2·19
23	39·420	318·76	85·16	·49	314·90	2·17
28	38·822	28·56	116·81	·46	315·32	2·16
Nov. 2	38·246	98·43	148·53	·42	315·75	2·14
7	37·699	168·36	180·31	·37	316·17	2·12
12	37·183	238·36	212·15	·33	316·60	2·11
17	36·704	308·42	244·05	·28	317·02	2·09
22	36·268	18·53	276·01	·23	317·45	2·07
27	35·881	88·68	308·01	·18	317·87	2·06
Dec. 2	35·543	158·87	340·05	·13	318·29	2·04
7	35·261	229·09	12·12	·09	318·71	2·02
12	35·037	299·31	44·19	·05	319·14	2·01
17	34·876	9·54	76·27	+ ·03	319·56	1·99
22	34·779	79·76	108·33	·00	319·98	1·97
27	34·747	149·96	140·38	·00	320·40	1·95
1907. Jan. 1	34·781	220·12	172·39	+0·00	320·82	+1·94

The following is a list of the Greenwich Mean Times when the adopted zero-meridians of the two systems will pass the middle of the illuminated disc, and the intervals between successive passages, to facilitate the determination of intermediate ones :—

System I.

d	h	m	Interval between Passages 9h + m	1905.	d	h	m	Interval between Passages 9h + m	1905.	d	h	m
8	1	43·43	50·63	Aug.	22	22	39·73	50·52	Nov.	6	19	13·73
0	2	56·55			24	23	52·30			8	20	25·76
2	4	9·66			27	1	4·86			10	21	37·79
4	5	22·76			29	2	17·40			12	22	49·82
6	6	35·84			31	3	29·92			15	0	1·85
8	7	48·91	50·61	Sept.	2	4	42·42			17	1	13·88
0	9	1·97			4	5	54·90			19	2	25·92
2	10	15·02			6	7	7·36			21	3	37·97
4	11	28·05			8	8	19·81			23	4	50·02
6	12	41·08			10	9	32·24			25	6	2·08
8	13	54·09	50·60		12	10	44·65	50·48		27	7	14·15
0	15	7·09			14	11	57·04			29	8	26·23
2	16	20·07			16	13	9·42		Dec.	1	9	38·31
4	17	33·04			18	14	21·77			3	10	50·40

SYSTEM I.

1906. d	h	m	Interval between Passages 9h+ m	1906. d	h	m	Interval between Passages 9h+ m	1906. d	h	m	Interval between Passages 9h+ m
Jan. 21	15	49·17		Apr. 9	14	8·08		Sept. 4	15	46·61	
23	17	1·97		11	15	21·42		6	16	59·35	
25	18	14·79		13	16	34·76		8	18	12·08	
27	19	27·64		15	17	48·10		10	19	24·79	
29	20	40·51		17	19	1·44		12	20	37·49	
31	21	53·40		19	20	14·78		14	21	50·17	50·54
Feb. 2	23	6·32	50·59	21	21	28·13		16	23	2·83	
5	0	19·26		23	22	41·48		19	0	15·48	
7	1	32·22		25	23	54·83	50·67	21	1	28·11	
9	2	45·21		28	1	8·18		23	2	40·72	
11	3	58·22		30	2	21·53		25	3	53·31	
13	5	11·24		May 2	3	34·88		27	5	5·89	
15	6	24·28		4	4	48·23		29	6	18·45	
17	7	37·34		July 15	9	23·14	50·62	Oct. 1	7	30·99	
19	8	50·42		17	10	36·25		3	8	43·51	
21	10	3·52		19	11	49·34		5	9	56·01	50·50
23	11	16·63	50·62	21	13	2·41		7	11	8·50	
25	12	29·76		23	14	15·47		9	12	20·97	
27	13	42·91		25	15	28·52		11	13	33·42	
Mar. 1	14	56·07		27	16	41·56		13	14	45·85	
3	16	9·24		29	17	54·59		15	15	58·27	
5	17	22·42		31	19	7·60		17	17	10·66	
7	18	35·61		Aug. 2	20	20·60		19	18	23·04	
9	19	48·82		4	21	33·58	50·59	21	19	35·41	
11	21	2·05		6	22	46·55		23	20	47·76	
13	22	15·29		8	23	59·51		25	22	0·09	50·46
15	23	28·53	50·65	11	1	12·45		27	23	12·40	
18	0	41·78		13	2	25·38		30	0	24·70	
20	1	55·04		15	3	38·29		Nov. 1	1	36·98	
22	3	8·31		17	4	51·18		3	2	49·23	
24	4	21·60		19	6	4·07		5	4	1·46	
26	5	34·89		21	7	16·94		7	5	13·68	
28	6	48·18		23	8	29·80		9	6	25·89	
30	8	1·48		25	9	42·64	50·57	11	7	38·08	
Apr. 1	9	14·79		27	10	55·46		13	8	50·26	
3	10	28·11		29	12	8·27		15	10	2·42	50·43
5	11	41·43	50·66	31	13	21·07		17	11	14·56	
7	12	54·75		Sept. 2	14	33·85		19	12	26·68	

System I.

6.	d	h	m	Interval between Passages 9^h+ m	1906.	d	h	m	Interval between Passages 9^h+ m	1906.	d	h	m
v.	21	13	38·80		Dec.	5	22	3·32	50·43	Dec.	20	6	27·
	23	14	50·90			7	23	15·37			22	7	39·
	25	16	2·99			10	0	27·41			24	8	51·
	27	17	15·07			12	1	39·44			26	10	3·
	29	18	27·14			14	2	51·46			28	11	15·
c.	1	19	39·21			16	4	3·48			30	12	27·
	3	20	51·27			18	5	15·51		1907. Jan.	1	13	39·

System II.

5.	d	h	m	m	1905.	d	h	m	m	1905.	d	h	m
ne	8	1	49·78	55·81	Aug.	4	23	57·10		Oct.	1	21	51·7
	10	3	28·78			7	1	35·70			3	23	29·8
	12	5	7·78			9	3	14·30			6	1	7·9
	14	6	46·77			11	4	52·89			8	2	46·0

SYSTEM II.

1905.	d	h	m	Interval between Passages 9^h + m	1906.	d	h	m	Interval between Passages 9^h + m	1906.	d	h	m	Interval between Passages 9^h + m
Nov.	28	19	35·10		Feb.	13	8	17·38		Apr.	30	21	25·90	
	30	21	13·06			15	9	56·32		May	2	23	5·16	
Dec.	2	22	51·03			17	11	35·27			5	0	44·41	55·85
	5	0	29·00	55·61		19	13	14·24						
	7	2	7·03			21	14	53·23		July	15	4	47·64	55·80
	9	3	45·09			23	16	32·24			17	6	26·64	
	11	5	23·17			25	18	11·26	55·80		19	8	5·62	
	13	7	1·28			27	19	50·30			21	9	44·59	
	15	8	39·40		Mar.	1	21	29·36			23	11	23·54	
	17	10	17·55			3	23	8·43			25	13	2·48	
	19	11	55·71			6	0	47·52			27	14	41·42	
	21	13	33·91			8	2	26·61			29	16	20·34	
	23	15	12·14			10	4	5·70			31	17	59·24	
	25	16	50·39	55·66		12	5	44·81		Aug.	2	19	38·13	
	27	18	28·68			14	7	23·94			4	21	17·01	55·77
	29	20	7·00			16	9	3·09			6	22	55·87	
	31	21	45·35			18	10	42·24	55·83		9	0	34·73	
1906. Jan.	2	23	23·72			20	12	21·40			11	2	13·56	
	5	1	2·12			22	14	0·57			13	3	52·38	
	7	2	40·54			24	15	39·74			15	5	31·19	
	9	4	19·00			26	17	18·93			17	7	9·97	
	11	5	57·51			28	18	58·13			19	8	48·75	
	13	7	36·05			30	20	37·32			21	10	27·52	
	15	9	14·62	55·72	Apr.	1	22	16·53			23	12	6·27	
	17	10	53·22			3	23	55·75			25	13	45·00	55·75
	19	12	31·85			6	1	34·97			27	15	23·72	
	21	14	10·52			8	3	14·19	55·84		29	17	2·42	
	23	15	49·22			10	4	53·42			31	18	41·11	
	25	17	27·93			12	6	32·66		Sept.	2	20	19·78	
	27	19	6·66			14	8	11·90			4	21	58·43	
	29	20	45·42			16	9	51·15			6	23	37·06	
	31	22	24·21			18	11	30·40			9	1	15·68	
Feb.	3	0	3·01			20	13	9·65			11	2	54·27	
	5	1	41·84	55·77		22	14	48·89			13	4	32·86	
	7	3	20·69			24	16	28·14			15	6	11·43	55·72
	9	4	59·56			26	18	7·40			17	7	49·98	
	11	6	38·46			28	19	46·65	55·85		19	9	28·52	

SYSTEM II.

m	Interval between Passages 9^h+ m	1906.	d	h	m	Interval between Passages 9^h+ m	1906.	d	h	m	Interval between Passages 9^h+ m
7·04		Oct.	26	14	59·07	55·64	Nov.	30	18	46·04	
45·54			28	16	37·26		Dec.	2	20	23·98	
24·01			30	18	15·43			4	22	1·92	
2·48		Nov.	1	19	53·59			6	23	39·84	55·61
40·93			3	21	31·72			9	1	17·77	
19·36			5	23	9·83			11	2	55·68	
57·77			8	0	47·93			13	4	33·59	
36·16	55·68		10	2	26·01			15	6	11·48	
14·54			12	4	4·08			17	7	49·38	
52·89			14	5	42·14			19	9	27·28	
31·23			16	7	20·18	55·61		21	11	5·19	
9·55			18	8	58·19			23	12	43·10	
47·85			20	10	36·19			25	14	21·01	
26·12			22	12	14·19			27	15	58·91	55·60
4·38			24	13	52·17			29	17	36·84	

If we call B″ the jovigraphical latitude of the centre of the disc, then $B'' = \left(\frac{a}{b}\right)^2 B = \left(\frac{15{\cdot}53}{14{\cdot}53}\right)^2 B$.

The longitudes of *Jupiter's* central meridian are computed with unaltered values of the rates of rotation and of the zero meridians in the two adopted systems. The addition of the "Corr. for Phase" gives the longitudes of the meridians which bisect the illuminated disc.

The sidereal periods of rotation corresponding to the two adopted systems are $9^h\ 50^m\ 30^s{\cdot}004$, $9^h\ 55^m\ 40^s{\cdot}632$.

Every fifth transit of each zero meridian across the centre of the illuminated disc is given ; any intermediate transit may be found by applying once or twice the interval between successive transits, this interval being also tabulated.

The continuation of this ephemeris is given in the *Nautical Almanac* for 1907, the same elements being used there except the equatorial and polar diameters and the light-time, which are altered to accord with those used elsewhere in the *Nautical Almanac.*

There will be a transit of the Earth across the Sun's disc as seen from *Jupiter* on 1906 December 27. For an observer at *Jupiter's* centre the Earth's centre would enter on the Sun's disc Dec. $27^d\ 21^h\ 49^m$ G.M.T., and would leave the Sun's disc Dec. $28^d\ 8^h\ 33^m$ G.M.T. ; the least distance of centres would be Dec. $28^d\ 3^h\ 11^m$, when the Earth's centre would be $67''{\cdot}5$ north of the Sun's centre ; the Sun's semi-diameter as seen from *Jupiter* would be $189''{\cdot}5$. The laws of recurrence of these transits were discussed in *Monthly Notices*, vol. lxi. 2, p. 117.

Satellite I. transits the disc of *Jupiter*, Dec. $28^d\ 12^h$, and the satellite will then partially occult its own shadow.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.* :
1905 *January* 7.

Ephemeris for Physical Observations of Saturn, 1905–6–7.

By A. C. D. Crommelin.

Paris Midnight.	Light Time.	Longitude of Central Meridian.		G.M.T. of Preceding Transit of Zero Meridian.			
		I. 843°·750.	II. 812°·641.	System I.		System II.	
1905.	m	°	°	h m		h m	
May 28	80·60	155·80	77·39	7 24·77	12	9 33·53	11
June 2	...	54·85	180·88	10 17·05	11	6 30·16	11
7	79·23	313·93	284·40	2 54·92	12	3 26·47	12
12	...	213·04	27·95	5 47·09	12	11 1·13	11
17	77·91	112·18	131·53	8 39·22	12	7 57·60	11
22	...	11·33	235·13	11 31·32	11	4 54·04	11
27	76·70	270·51	338·74	4 9·03	12	1 50·46	12

Light Time.	Longitude of Central Meridian.		G.M.T. of Preceding Transit of Zero Meridian.					
	I. 843°·750.	II. 812°·641.	System I.			System II.		
m	°	°	h	m		h	m	
...	169·71	82·38	7	1·04	12	9	24·69	11
75·60	68·92	186·03	9	53·04	11	6	21·05	11
...	328·14	289·69	2	30·69	12	3	17·39	12
74·66	227·36	33·36	5	22·68	12	10	51·54	11
...	126·58	137·03	8	14·65	12	7	47·86	11
73·93	25·79	240·69	11	6·64	11	4	44·20	11
...	285·00	344·35	3	44·30	12	1	40·52	12
73·40	184·19	87·99	6	36·34	12	9	14·71	11
...	83·36	191·61	9	28·40	11	6	11·16	11
73·11	342·51	295·21	2	6·15	12	3	8·14	12
...	241·62	38·78	4	58·33	12	10	41·94	11
73·08	140·70	142·32	7	50·55	12	7	38·48	11
...	39·75	245·82	10	42·82	11	4	35·08	11
73·28	298·76	349·28	3	20·81	12	1	31·76	12
...	197·71	92·70	6	13·24	12	9	6·39	11

Paris Midnight.	Light Time.	Longitude of Central Meridian. I. 843°·750.	II. 812°·641.	G.M.T. of Preceding Transit of Zero Meridian. System I.		System II.	
1906.	m	°	°	h m		h m	
Jan. 8	...	278·12	40·32	3 55·93	12	10 39·19	11
13	87·46	176·16	142·82	6 49·96		7 37·54	
June 2	80·85	212·42	143·68	5 48·14	12	7 36·07	11
7	...	111·42	247·13	8 40·51	12	4 32·77	11
12	79·45	10·45	350·60	11 32·82	11	1 29·44	12
17	...	269·51	94·10	4 10·72	12	9 3·91	11
22	78·09	168·60	197·63	7 2·93	12	6 0·49	11
27	...	67·72	301·19	9 55·08	11	2 56·99	12
July 2	76·79	326·87	44·77	2 32·85	12	10 31·33	11
7	...	226·03	148·37	5 24·94	12	7 27·77	11
12	75·60	125·21	252·00	8 16·99	12	4 24·15	11
17	...	24·42	355·64	11 8·97	11	1 20·53	12
22	74·52	283·63	99·30	3 46·65	12	8 54·71	11
27	...	182·84	202·96	6 38·64	12	5 51·05	11
Aug. 1	73·64	82·06	306·63	9 30·62	11	2 47·36	12
6	...	341·28	50·29	2 8·26	12	10 21·55	11
11	72·94	240·49	153·95	5 0·27	12	7 17·88	11
16	...	139·69	257·60	7 52·28	12	4 14·23	12
21	72·46	38·87	1·23	10 44·32	11	11 48·47	11
26	...	298·02	104·84	3 22·08	12	8 44·89	11
31	72·24	197·15	208·42	6 14·21	12	5 41·37	11
Sept. 5	...	96·26	311·97	9 6·38	11	2 37·88	12
10	72·25	355·32	55·49	1 44·28	12	10 12·33	11
15	...	254·34	158·97	4 36·60	12	7 8·97	11
20	72·51	153·32	262·41	7 29·01	12	4 5·69	12
25	...	52·25	5·79	10 21·48	11	11 40·39	11
30	73·03	311·12	109·13	2 59·69	12	8 37·28	11
Oct. 5	...	209·94	212·41	5 52·36	12	5 34·27	11
10	73·77	108·70	315·64	8 45·14	12	2 31·34	12
15	...	7·41	58·82	11 38·00	11	10 6·43	11
20	74·70	266·06	161·94	4 16·57	12	7 3·69	11
25	...	164·66	265·00	7 9·63	12	4 1·05	12
30	75·80	63·20	8·00	10 2·79	11	11 36·47	11
Nov. 4	...	321·68	110·95	2 41·63	12	8 34·03	11
9	77·03	220·10	213·84	5 34·99	12	5 31·68	11
14	...	118·48	316·68	8 28·43	12	2 29·44	12
19	78·35	16·81	59·48	11 21·96	11	10 5·24	11

ris ight.	Light Time.	Longitude of Central Meridian.		G.M.T. of Preceding Tr Zero Meridian.				
		I. 843°·750.	II. 812°·641.	System I.			Sys	
06.	m	°	°	h	m		h	
. 24	...	275·08	162·23	4	1·14	12	7	
29	79·72	173·32	264·94	6	54·83	12	4	
. 4	...	71·52	7·61	9	48·57	11	11	3
9	81·09	329·69	110·25	2	27·92	12	8	3
14	...	227·82	212·85	5	21·80	12	5	3
19	82·43	125·93	315·42	8	15·70	12	2	3
24	...	24·01	57·97	11	9·67	11	10	
29	83·70	282·07	160·51	3	49·19	12	7	
07.								
3	...	180·12	263·03	6	43·20	12	4	
8	84·87	78·17	5·54	9	37·23	11	11	4
13	...	336·20	108·03	2	16·80	12	8	3
18	85·91	234·22	210·52	5	10·85	12	5	3
23	...	132·26	313·02	8	4·89	12	2	3
28	86·80	30·29	55·52	10	58·96		10	1

The times of transit of zero meridian are given above for the true centre of the disc. If the times are required for the centre of the illuminated disc the following correction should be applied, being subtracted before opposition and added after it.

Days from Opposition.	Correction Min.	Days from Opposition.	Correction Min.	Days from Opposition.	Correction Min.
5	0·00	55	0·19	105	0·26
10	·01	60	·21	110	·24
15	·02	65	·23	115	·23
20	·04	70	·25	120	·21
25	·06	75	·26	125	·19
30	·08	80	·27	130	·17
35	·10	85	·28	135	·15
40	·12	90	·28	140	·12
45	·15	95	·27	145	·10
50	·17	100	·27	150	·08

Erratum in Mr. Franks's Paper.

Page 159, 6th line from bottom, *for* darkness *read* thickness.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXV. FEBRUARY 10, 1905. No. 4

ANNUAL GENERAL MEETING.

Professor H. H. TURNER, D.Sc., F.R.S., PRESIDENT, in the Chair.

The Report of the Auditors of the Treasurer's accounts for the year 1904 was read, and is given on p. 326.

The Annual Report of the Council was partly read; see pp. 323 to 411.

The Address was delivered by the President, after which the Gold Medal was handed to His Excellency the American Ambassador for transmission to Professor Lewis Boss, to whom the Medal had been awarded for his long-continued work on the positions and proper motions of Fundamental Stars (see pp. 412 to 425).

The President also announced that the Jackson-Gwilt Gift and Bronze Medal had been awarded to Mr. John Tebbutt, of Windsor, New South Wales, for his important observations of Comets and Double Stars, and his long-continued services to astronomy in Australia, extending over forty years. The Medal was then handed to the Secretary for transmission to Mr. Tebbutt.

The President handed to the Assistant Secretary a cheque for 140*l*. as a testimonial from the Fellows of their appreciation of his devotion to the service of the Society for the past thirty years.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 426.

The thanks of the Meeting were given to the retiring Officers, and also to the Auditors of the Treasurer's Accounts and to the Scrutineers of the ballot.

William Edward Raymond, Astronomical Observer, Sydney Observatory, New South Wales, Australia,

was balloted for and duly elected a Fellow of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

William Bowyer, Established Computer, Royal Observatory, Greenwich (proposed by Thomas Lewis);
Rev. Thomas Joseph Charlton, The Rectory, Omeath, Co. Louth, Ireland (proposed by Dr. J. S. Slater);
Captain Louis Arthur D'Emres, Chief Examiner for Masters and Mates, Marine and Fisheries Department, Ottawa, Canada (proposed by Captain P. Thompson);
David James Reginald Edney, Established Computer, Royal Observatory, Greenwich, Teston Lodge, Blackheath Rise, Lewisham, S.E. (proposed by W. W. Bryant);
Herbert Henry Furner, Established Computer, Royal Observatory, Greenwich (proposed by F. W. Dyson);
John Adelbert Parkhurst, M.Sc., Yerkes Observatory, Williams Bay, Wis., U.S.A. (proposed by H. H. Turner);
Montagu Austin Phillips, 22 Petherton Road, Highbury New Park, N. (proposed by F. W. Levander); and
A. L. Wood, Teacher of Navigation, H.M.S. "Conway," Rock Ferry, Birkenhead (proposed by W. G. Thackeray).

Report of the Council to the Eighty-fifth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron and Hon. Members	Grand Total
1903 December 31	266	377	643	47	3	693
Since elected	+ 2	+ 29	...	+ 3	...	...
Deceased	− 9	− 11	...	− 1	...	...
Resigned	...	− 7	...	...	...	...
Removals	+ 3	− 3	...	...	...	...
Expelled	...	− 3	...	...	...	...
1904 December 31	262	382	644	49	3	696

Mr. Maw's Account as Treasurer of the Royal

RECEIVED.

	£	s.	d.	£	s.	d.
1903 December 31 :—						
Bankers', as per Pass-book	246	9	5			
ntry Cheque not credited till 1904 ...	9	16	0			
and of Assistant Secretary on Petty Cash Account	4	10	10			
				260	16	3
on £1,250 Metropolitan 3-per-cent. Stock	35	13	5			
on £932 19 0 Metropolitan 2½-per-cent.	22	3	9			
on £3,400 East Indian Railway 3-per- Debenture Stock	97	0	1			
on £3,200 London and North-Western ay 3-per-cent. Debenture Stock	91	10	0			
on £4,000 Midland Railway 2½-per- Debenture Stock	95	6	3			
on £500 Lancashire and Yorkshire Rail- per-cent. Consolidated Preference Stock	14	5	11			
on £1,860 Gas Light and Coke Co. ent. Debenture Stock	53	3	8			
on £1,650 Commercial Gas Co. 3-per- Debenture Stock	47	1	6			

Astronomical Society, from 1904 *January* 1 *to December* 31.

PAID.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
„ „ For editing Society's Publications	50	0	0			
„ „ Special grant	10	0	0			
				310	0	0
House Duty	2	12	6			
Fire Insurance	9	9	6			
				12	2	0
Printing, plates, &c., *Memoirs*, vol. liv. (Spottiswoode & Co.)	203	13	6			
Printing, plates, &c., *Monthly Notices* (Spottiswoode & Co.)	540	6	3			
Printing, plates, &c., Appendix to *Memoirs* (Harrison & Sons)	66	12	10			
Printing, plates, &c., Appendix to *Monthly Notices* (Harrison & Sons)	14	7	0			
Printing List of Fellows and Miscellaneous (Spottiswoode & Co.)	29	16	6			
Photo-plates for *Monthly Notices* (A. E. Dent & Co.)	17	17	11			
				872	14	0
Computation of Ephemerides in *Monthly Notices* ...				15	0	0
Purchase of books for Library: from Council Grant	10	0	0			
Do. from Turnor and Horrox Fund ...	6	14	0			
				16	14	0
Binding books in Library				45	8	6
Reproduction of Photographs, Hinton & Co. ...				42	4	8
Cataloguing astronomical literature for the International Catalogue				30	0	0
Clerk's Wages	53	0	0			
Postage and Telegrams	92	3	8			
Carriage of Parcels, &c.	9	13	8			
Stationery (Spottiswoode & Co.)	8	14	3			
Sundry Stationery and Office Expenses	4	3	9			
				167	15	4
Expenses of Meetings	21	14	0			
Lantern Expenses	10	16	5			
Time Signal: Rental of Wire	5	0	0			
				37	10	5
House Expenses	62	15	6			
Coal and Gas	39	14	8			
Electric Light Expenses	6	10	6			
Fittings, Repairs, &c.	22	12	1			
Sundry ditto	8	18	5			
Sundries	4	15	7			
				145	6	9
Lee and Janson Fund: grant to Mrs. Hopkins				10	0	0
Deductions on Cheques, &c.				0	1	8
Repayment to Assistant Secretary of amount due 1903 Dec. 31 on Account of Turnor and Horrox Fund				2	8	3
Balances, 1904 December 31:—						
At Bankers', as per Pass-book	252	7	5			
In hand of Assistant Secretary on Account of Turnor and Horrox Fund...	9	17	9			
				262	5	2
				£1,969	10	9

Report of the Auditors.

ave examined the Treasurer's accounts of receipts and ure for the year 1904, and have found and certified the be correct. The cash in hand on December 31, 1904, g the balance at the bankers', &c., amounted to 2*d.*

invested property of the Society is the same as at the e previous year.

books, instruments, and other effects in the possession of ety have been examined, and they appear to be in a ory condition.

have laid on the table a list of the names of those who are in arrear for sums due at the last Annual Meeting of the Society, with the amount due against low's name.

(*Signed*) C. THWAITES.

Assets and Present Property of the Society, 1905 *January* 1.

	£	s.	d.	£	s.	d.
Balances, 1904 December 31 :—						
At Bankers', as per Pass-book	252	7	5			
In hand of Assistant Secretary on account of Turnor and Horrox Fund...	9	17	9			
	262	5	2			
Less due to Assistant Secretary on Petty Cash Account	9	10	0			
				252	15	2
Due on account of Subscriptions :—						
1 Subscription of 5 years' standing	10	10	0			
4 „ 4 „	33	12	0			
12 „ 3 „	75	12	0			
36 „ 2 „	151	4	0			
56 „ 1 year's standing	117	12	0			
4 Admission Fees and First Contributions ...	12	12	0			
	401	2	0			
Less 1 Subscription paid in advance	2	2	0			
				399	0	0
Due for Photographs sold				0	11	0
Due from Messrs. Williams & Norgate for sales of Publications during 1904				33	18	6

£3,400 East Indian Railway 3-per-cent. Debenture Stock, including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (*née* Gwilt) Fund.

£3,200 London and North-Western Railway 3-per-cent. Debenture Stock.

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£1,650 Commercial Gas Company 3-per-cent. Debenture Stock.

£500 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock.

£1,250 Metropolitan 3-per-cent. Stock.

£932 19*s.* 0*d.* Metropolitan 2½-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

Two Gold Medals.

Celestial Photographs.

following is a list of reproductions of Celestial Photographs
ed by the Royal Astronomical Society for sale to the
:—

Subject.	Photographed by
l Solar Eclipse, 1889 January 1	W. H. Pickering
l Solar Eclipse, 1893 April 16	J. M. Schaeberle
l Solar Eclipse, 1886 August 29	A. Schuster
læ in the *Pleiades*	Isaac Roberts
la M 74 *Piscium* (N.G.C. 628)	Isaac Roberts
t Nebula in *Orion*	Isaac Roberts
y Way near M 11	E. E. Barnard
y Way near Cluster in *Perseus*	E. E. Barnard
et *c* 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
et *a* 1892 I. (Swift), 1892 April 7	E. E. Barnard

R.A.S. Ref. No.	Subject.	Photographed by
34	Portion of Moon (Mare Serenitatis)	Lick Observatory
35	Portion of Moon (Clavius, Licetus, &c.)	Lick Observatory
36	Portion of Moon (Regiomontanus, &c.)	Lick Observatory
37	Portion of Moon (Tycho, Thebit, &c.)	Lick Observatory
38	Portion of Moon (Theophilus, &c.)	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ* (N.G.C. 6779)	
42	Nebulæ M 81, 82 *Ursæ Majoris* (N.G.C. 3031, 3034)	
43	Cluster M 56 *Lyræ* (enlarged) (N.G.C. 6779)	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 September 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*	W. E. Wilson
57	Dumb-bell Nebula, *Vulpecula* (N.G.C. 6853)	W. E. Wilson
58	Spiral Nebula, *Canes Venatici* (N.G.C. 5194)	W. E. Wilson
59	Ditto (enlarged) (N.G.C. 5194)	W. E. Wilson
60	Annular Nebula, *Lyra* (N.G.C. 6720)	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 November 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*	Roy. Obs., Greenwich
67	Spectrum of Sun's limb, 1898 January 22	E. H. Hills
68	Annular Nebula, *Lyra* (N.G.C. 6720)	Lick Observatory
69	Dumb-bell Nebula, *Vulpecula* (N.G.C. 6853)	Lick Observatory
70	Spiral Nebula, *Canes Venatici* (N.G.C. 5194-5)	Lick Observatory
71	Spiral Nebula, *Ursa Major* (N.G.C. 5457)	Lick Observatory
72	Trifid Nebula, *Sagittarius* (N.G.C. 6514)	Lick Observatory

...bject.	Photographed by
...	Lick Observatory
... (N.G.C. 6205)	Lick Observatory
...aculæ	G. E. Hale
...ences	G. E. Hale
..., 1898 Jan. 22 (⅔ sec.)	W. H. M. Christie
...ygni (N.G.C. 6992)	W. E. Wilson
...Theophilus, &c.)	Yerkes Observatory
...se, 1900 May 28 (30 sec.)	E. E. Barnard
...1901 May 4	Roy. Obs., Cape of G. H.
... 1901 May 6	Roy. Obs., Cape of G. H.
..., 1901 May 9	Perth Obs., W. Australia
... with Faculæ	H. Deslandres
...ences	H. Deslandres
...t Nova Persei, 1901 September 20	G. W. Ritchey
...ut Nova Persei, 1901 November 13	G. W. Ritchey
...r Eclipse, 1901 May 18 (10 sec.)	F. W. Dyson
...r Eclipse, 1901 May 18 (40 sec.)	F. W. Dyson
...1902 III. (Perrine), 1902 Sept. 29	Roy. Obs., Greenwich
...of Moon (Mare Serenitatis, &c.)	Yerkes Observatory
...of Moon (Rough Crater Region,	Yerkes Observatory
...	Yerkes Observatory
...ophilus, &c.)	Yerkes Observatory
...	...atory

R.A.S. Ref. No.	Subject.	Photographed by
111	Milky Way near χ *Cygni*	E. E. Barnard
112	Star cloud in *Sagittarius*	E. E. Barnard
113	Milky Way in *Cepheus*	E. E. Barnard
114	Milky Way about M 8	E. E. Barnard
115	Milky Way about θ *Ophiuchi*	E. E. Barnard
116	Milky Way near N.G.C. 6475	E. E. Barnard
117	Great Nebula near ρ *Ophiuchi*	E. E. Barnard
118	Milky Way about 58 *Ophiuchi*	E. E. Barnard
119	Milky Way near *Omega* nebula	E. E. Barnard
120	Star cloud in *Sagittarius*	E. E. Barnard
121	Nebula about ν *Scorpii*	E. E. Barnard

Nos. 44–55 and Nos. 64 and 65 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs are now on sale to Fellows as prints, either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches, and also as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, 6¼ inches square.

Price of prints, 1*s.* 6*d.* each; lantern slides, 1*s.* each; packing and postage extra.

Unmounted prints, 1*s.* each, can be obtained to order.

Transparencies, 6¼ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Professor Lewis Boss for his long-continued work on the positions and proper motions of Fundamental Stars. The President will lay before the Society the grounds upon which the award has been founded.

The Jackson-Gwilt Gift and Medal.

The Hannah Jackson (*née* Gwilt) Gift and Bronze Medal have been awarded to Mr. John Tebbutt for his important observations of Comets and Double Stars, and his long-continued services to astronomy, extending over forty years.

Publications of the Society.

the past year vol. lxiv. of the *Monthly Notices* has
l.

rdance with the arrangement made with the Royal
entioned in previous Annual Reports, four Appendices
. have been issued.

lowing volumes of the *Memoirs* have been published :—

. containing :

W. Brown, Theory of the Motion of the Moon.
Coleman, Measures of Double Stars.
. W. Sidgreaves, Connexion between Solar Spots and
Earth-magnetic Storms.
M. Seabroke [&c.], Measures of Double Stars at the
Temple Observatory, Rugby.
H. Maw, Double-star Observations, 1899–1901.
T. A. Innes, Some Developments in Terms of the
Mean Anomaly.
A. Sampson, Description of Adams's MSS. on the

OBITUARY.

The Council regret that they have to record the loss by death of the following Fellows and Associate during the past year :—

Fellows :—William Anderson.
John Mackenzie Bacon.
Reginald Bushell.
Robert Prichard Davies.
Rev. Charles Evans.
William Francis.*
J. Horsley Haslam.
Rev. Andrew Henderson.
George E. Lumsden.
Frank McClean.
William Grant MacGregor.†
William Noble.
Sir Erasmus Ommanney.
William Montgomery Pierson.
Eyre Burton Powell.
Walter J. B. Richards.
Isaac Roberts.
Maurice Allen Smelt.
John Steele.
Sir Henry Thompson.
Associate :—Theodor Bredichin.

Obituary notices are also given of the following, who died in January 1905 :—

Edward Crossley.
Charles Horsley.
Paul Henry (Associate).

WILLIAM ANDERSON, the eldest son of Thomas Anderson, of Ballymena, co. Antrim, was born on the 7th of February 1870. He was educated at the Royal Academical Institution, Belfast, and on leaving entered the linen business. After a few years his health made it necessary for him to leave Ireland. He went to Madeira and afterwards to Jamaica, taking with him a 5-inch

* Obituary in *Annual Report*, 1904.
† Died in December 1903, but death not reported till 1904.

r by Grubb. He was elected a Fellow of the Royal mical Society on the 10th of April 1896, and was also a of the British Astronomical Association. He contributed *Ionthly Notices* of April 1898 a paper on the "Zodiacal and in the same year sent letters to the Journal of the Astronomical Association and to the *Observatory* on the l Light and Gegenschein. He also sent to the British mical Association papers on sun-spots, on *Saturn's* rings, vings of *Jupiter*.

Anderson married in 1891 Margaret, daughter of Robert of Ballymena. He died in Jamaica on the 28th of 904, leaving a widow and one son.

REV. JOHN MACKENZIE BACON was born on the 19th of 46 at Lambourne, Woodlands, Berks. He was the son of John Bacon and great-grandson of John Bacon, R.A., the He studied at Trinity College, Cambridge, but failure h obliged him to take an Ægrotat degree in 1870. He ined the same year, but never held a living or undertook an temporary clerical duty.

ealth compelled him to leave the tutorial work he had ken at Cambridge, and in 1876 he went to Coldash,

REGINALD BUSHELL was born on 18th of August 1842 at Aigburth, near Liverpool. He was the second son of Mr. Christopher Bushell, a well-known member of the Liverpool Dock Board. Mr. Bushell was in business in Liverpool for many years, and was a member of the Mersey Docks and Harbour Board for seventeen years. He was a director of the Liverpool Overhead Railway and of the Sea Insurance Company. Mr. Bushell was interested in education, and was intimately connected with the Liverpool University from its foundation. He was a member of the Liverpool Council of Education and of other educational bodies in Lancashire and Cheshire, and was a justice of the peace for Cheshire. Mr. Bushell's scientific interests were meteorology and horology. He became, through his interest in clocks, an expert mechanician, and designed and executed several turret clocks which performed extremely well. In order to determine time he made himself a practised meridian observer. He was elected a Fellow of the Royal Astronomical Society on the 12th of May 1871.

Mr. Bushell died suddenly on the 11th of November 1904, at his residence at Hinderton Lodge, Neston, Cheshire, and leaves a widow, two sons, and one daughter.

EDWARD CROSSLEY was born in 1841. He was educated at private schools, and for a short time at Owens College, Manchester. In his sixteenth year he entered business in the firm of Messrs. John Crossley & Sons, carpet manufacturers, Halifax, the heads of which were his father and two uncles. He ceased to take an active share of the work of this firm when he was returned to Parliament for the Sowerby Division in 1885 to 1892. His Parliamentary work soon came to an end owing to indifferent health. Till his death he was chairman of the directors of the firm of John Crossley & Sons.

From boyhood he had a taste for astronomy, and, beginning with a 3-inch telescope, he went on to a 7-inch equatorial. In 1868 he built an observatory about 18 feet square, with a dome, in a space behind his house on the edge of the town. Here in 1869 Mr. J. Gledhill joined him. In 1872 Mr. Crossley built a house about two miles south of Halifax; and at the west side of the house the present observatory was built, with equatorial and meridian instruments. The equatorial was of 9-inch aperture by Cooke of York, and was fitted with driving clock, micrometers, and other apparatus. The meridian instrument was a 3½-inch transit circle by Cooke; in another room he had a small equatorial at one time, then a 7-inch equatorial, and afterwards a 4½-inch (new triple-glass) equatorial by Messrs. T. Cooke & Sons. With these instruments measures of double stars and observations of planetary phenomena, occultations of stars by the Moon, &c., were made. Mr. Crossley was also much interested in the measurement of base lines. He devised some ingenious measuring-rods, set up a measuring

[redacted] 3-foot, 40-inch, and 10-foot bars and rods. [redacted]ed the late Dr. Common's 3-foot reflecting [redacted]an observatory with an iron dome about 40 [redacted]After spending some years in improving the [redacted]of the instrument and trying to use it for [redacted]hy, he presented it to the Lick Observatory, [redacted]lifax being found quite unsuitable for so large [redacted]9-inch object-glass of the equatorial was sold a [redacted] one of Cooke's new triple object glasses was [redacted]He was elected a Fellow of the Royal Astro-[redacted]n the 14th June 1867.

[redacted]lied suddenly on the 21st of January 1905.

[redacted] P. DAVIES was born in 1823 at Llanddulas, in [redacted]which parish his father was then Rector. On his [redacted] to Liverpool he received his early education at [redacted]hool in that city. Thence he proceeded to Corpus [redacted] Cambridge, where he took his degree in 1845 as [redacted]angler.

[redacted]ained to the curacy of Easington, in Yorkshire, in [redacted]he removed to Hertfordshire, becoming incumbent [redacted]hurch and district of St. Mary, in the parish of [redacted]re he remained for twenty years, and in 1869 he [redacted] Sir T. S. Bazley, Bart., the living of Hatherop, in [redacted]e, which he retained till his death thirty-five years [redacted]

[redacted]nuch interested in astronomy, and was a careful [redacted] became a Fellow of the Royal Astronomical Society [redacted]f March 1869. For some forty years he had an [redacted]telescope and a good transit in-[redacted]

and Denmark Park, and was in much request as a lecturer. He was elected a Fellow of the Society on the 14th of March 1902.

In 1875 Mr. Haslam married Ellen Marianne, daughter of William Gorham, of Tonbridge. He had three children, two of whom survive him. Last year his strength began to fail, and he was advised to go to Switzerland; while there an operation became necessary, but he had not strength to rally from it. He was buried at Lucerne, where he died on the 27th of August 1904.

Andrew Henderson was born at Kirkwall on the 4th of January 1825. While still a child his parents removed to Dundee, where he was educated at Tay Square and Dundee Academies. In 1839 he entered the College of St. Andrews, of which Sir David Brewster was then Principal. Mr. Henderson was ordained in 1847, and became minister of the United Presbyterian Church at Coldingham, Berwickshire, till 1855, when he became minister of the United Presbyterian Church at Paisley, where he remained till his death, though in 1897 he had partially retired from active ministerial work.

In 1857 Henderson, with a few others, revived the Paisley Philosophical Society, of which he was President for eight years; he was prominent in connexion with every educational institution in the town, especially the Paisley Technical College and the Paisley Grammar School. In 1888 he took a large share in building and equipping the Camphill School, then the largest elementary school in Scotland; and only a fortnight before his death he visited the Technical College to inspect the new apparatus which had been supplied for the laboratories. He was at the head of the Committee of Management of the Astronomical Observatory founded by the late Thomas Coats, the instrumental equipment of which was entirely arranged by Dr. Henderson, who published in 1899 a small work, *The Coats Observatory: its History and Equipment.* His interest in astronomy led him to deliver numerous astronomical lectures in Paisley, while his energy and administrative ability made him a prominent member of nearly every educational board and committee of the charitable institutions of Dundee. In 1887 the University of St. Andrews conferred on him the degree of LL.D. He was elected a Fellow of the Royal Astronomical Society on the 9th of January 1885.

He died on the 29th of October 1904.

Charles Horsley was born on the 30th of May 1829 at Pye Bridge, Derbyshire, and educated at Derby Grammar School. After a few years spent at various engineering works he came to London and acted as agent and consulting engineer to Messrs. James Oakes & Co., of Alfreton, Derbyshire, a position he held until his death. He was elected a Member of the Institute of Civil Engineers in 1883, and was President of the Society of

s in 1881. He invented a gas exhauster and also a
phon, which have since been extensively used.
354 he married Louisa, daughter of Reuben Young, of
am.
nany years he was an active member of the magisterial
r Middlesex, and in 1887 was one of the 60 chosen to
the work during the time that the Cities of London and
ster were being amalgamated under the title of County
n. He was a member of the first London County Council,
for 18 years Chairman of the East Islington Conservative
ion.
Horsley was elected a Fellow of the Society on the
pril 1884. He died on the 4th of January 1905.

he death of Mr. Frank McClean, LL.D., F.R.S.,
astronomy loses not only an assiduous worker whose
ympathies ensured for all his work a high standard of
and finish, not only one whose enterprise carried his
f the sky over both hemispheres, and whose insight
for the first time direct evidence of the presence of
utside our planet, but also one of those whose lavish
y aided and inspired the work of many others. It

Square and then at 1 Onslow Gardens), the greater part of his scientific work was done at Tunbridge Wells.

His first interests (in 1872) were not astronomical, being centred in electrical work on coils; but in 1875 an observatory was completed at Ferncliffe, and he began an examination of stellar spectra, devising a spectroscopic eyepiece for the purpose which was introduced to general notice by the late Mr. John Browning at one of the Royal Society's *soirées*, and has since become a well-established instrument. But his first published paper is dated some twelve years later than this, and shows that his thoughts had taken a new direction.

In 1889 he presented to the Royal Astronomical Society his "Photographs of the Red End of the Solar Spectrum," comprising just half the visible spectrum from λ 5800 to λ 7700, whereas Dr. Rowland's published photographs extended from λ 3900 to λ 5800. Alongside the photographs of the red end subsidiary photographs of the green to violet spectrum were given, so that there were exceptional facilities for determining the scale value. This thoroughness was characteristic of the work of Mr. McClean. Within a year he presented to the same Society parallel photographs of the spectra of the Sun, of iron, and of iridium; and within a few years other series of comparative pictures of high and low Sun spectra, and solar and metallic spectra. All these photographs were on a large scale, and afforded valuable information to those working at such spectra. The instrument employed at this time was a telescope stopped down to four inches aperture, of 98 inches focal length, fixed parallel to the polar axis, the sunlight being reflected into it by means of a heliostat mounted on the roof of Mr. McClean's house at Tunbridge Wells. From 1879 to 1890 a large Rutherford grating was used; in 1890 a Rowland plane grating was obtained and substituted. In taking the photographs of high and low Sun spectra particular attention was paid to two points: first, a method of screening different parts of the spectrum by means of glass cells an inch thick filled with coloured solutions; secondly, the special preparation of the photographic plates. All such work as this Mr. McClean undertook with his own hands. Some of the metallic spectra are those of rare metals not easily obtainable.

In 1895 Mr. McClean ordered from Sir H. Grubb a telescope of the pattern adopted for the Astrographic Chart, but with the addition of an objective prism with an angle of 20°; and he commenced a systematic survey of the spectra of the stars brighter than 3½ magnitude in the northern heavens. This work was completed in 1896; and in 1897 Mr. McClean carried the prism with him to the Cape of Good Hope and mounted it on the telescope at the Royal Observatory of the same pattern as his own. He thus extended his survey to the whole sky—a notable achievement for a man working single-handed. For this work he received the Gold Medal of the Royal Astronomical Society in 1899. From the survey he deduced important con-

respecting the distribution of stars of different spectral
ınd he discovered the presence of oxygen in the star
and other helium stars.

main part of the northern survey is published in the
ociety's *Philosophical Transactions*, vol. cxci. ; but the
survey was published separately in a quarto volume of
and 30 plates, under the title *Spectra of Southern Stars.*
n Nova *Persei* appeared Mr. McClean, though a man of
terests and engagements, put all aside to devote himself
ectrum of the new star, and obtained a valuable series
graphs, enlargements of which he presented to the
No reproductions of these were, however, published in
thly Notices along with the brief descriptions (see vol. lxi.
386), as is the case also with his earlier photographs of
spectra, &c. Perhaps the time has come when the
ion of this omission may be considered.

independently of this work of a purely scientific kind,
Clean has claims on the gratitude of astronomers for his
nt gifts and bequests to their science. In 1890 he
at the University of Cambridge three Isaac Newton
hips for the encouragement of study and research in
ny (especially gravitational astronomy) and physical

bridge, are described as the most notable bequest made to it since its foundation. And as an artist he could not bear the touches of an alien hand to his work. Probably also his interest went deeper than with the majority of men, for in some of his benefactions also he spent much personal time and trouble in the settlement of the details. Thus, when he determined to present a large telescope to the Cape Observatory he spent many months in an attempt to devise an object-glass of a special kind, working out the numerical calculations himself, and also designed a special form of mounting. And although he was compelled ultimately to give up the object-glass, his ideas are incorporated in the mounting.

Of his originality no better proof could be offered than his discovery of oxygen in *β Crucis*. Such discoveries are sometimes so immediately confirmed by others that it almost seems a matter of chance who should be the first to make them; but it was very different in this case. Even after the publication of full details it was many months before the announcement was received with anything but mistrust; and in his address on presenting our Gold Medal to Mr. McClean in 1899 the President referred to this particular achievement in the most guarded language. A minor illustration of Mr. McClean's originality is afforded by his method of dividing the heavens for his survey according to galactic latitude and longitude (instead of according to the co-ordinates in vogue, which unnecessarily import terrestrial relations); a method which brings out at once several important features of distribution; as, for instance, that the helium stars are mainly congregated in the two zones north and south of the galactic equator. Finally, a further reference may be made to one of his numerous benefactions—viz. the Isaac Newton Studentships, which aim at securing more *workers* for astronomy in this country as opposed to the provision of instruments to work with. That Mr. McClean was in full sympathy with the latter and more familiar form of benefaction he gave ample proof in other directions; but this did not prevent him encouraging workers by a method which is unfortunately only too rare. We must go back a century and a half to find a similar encouragement; for the Sheepshanks Scholarship at Cambridge is not only so small in amount as to have in itself little directive force, but differs from the Isaac Newton Studentships in being provided, as a memorial, by a number of persons. A better parallel to the studentships is to be found in the astronomical professorships at Oxford and Cambridge, founded in 1619 by Savile, in 1704 by Plume, and in 1749 by Lowndes. Since 1749 no noteworthy endowment of an astronomical career in this country has been made by an individual; and, though Mr. McClean's endowment only makes provision for the outset of a career, its directive force has already been abundantly manifested.

Mr. McClean received the honorary degree of LL.D. from the

... in 1894. He was elected a Fellow of our ... the Royal Society in 1895. He served ... continuously from 1891, but could never ...pt office, nor to serve on the Council of ... He married in 1865 Ellen, daughter of ...scowbeck, Lancaster, and leaves three sons ...

H. H. T.

... MacGregor was born in 1838 in Strathspey, ...ch of the clan had been long settled. In his ...me to London, his parents apprenticing him ...rchant. He entered into business on his own ... In London he was attracted by Mr. Spurgeon's ... many years took an active part in the Sunday-...ses, &c., connected with Mr. Spurgeon's Church, ... of the Stockwell Orphanage.

... in astronomy was derived from his kinsman ...an of astronomy, whom he assisted to translate ... *Astronomy*. He was elected a Fellow of the ...3th of May 1892. He was also a Fellow of the ...ical Society, of the Royal Colonial Institute, and ...sh societies. He died on the 21st December 1903.

...illiam Noble, the eldest son of William Noble, ... Tweed, was born in 1828. After being privately ...ntered the Army, from which he retired with ...ptain. In 1851 he married Emily Charlotte, only ...rd Irving, of H.M. 61st Regiment. After his ... he settled at Forest Lodge, Maresfield, ... public duties. He was a ...

He was elected a Fellow of the Royal Astronomical Society on the 8th of June 1855, and has been a most constant attendant at the meetings. He frequently spoke, often contributing a shrewd observation and an amusing anecdote to the discussion. He served on the Council from 1866 to 1879, and with two short intervals from 1886 to 1904.

Captain Noble assisted in the foundation of the British Astronomical Association, and was chosen as its first President, the assistance and impetus he had given to amateur astronomy clearly marking him out for this post.

The humour and invariable cheerfulness of Captain Noble, combined with his deep interest in the welfare of the Royal Astronomical Society and of astronomy in general, made him very welcome and valuable both at the Council and the meetings of the Society.

Captain Noble died on the 9th of July 1904 after an illness of several months' duration. Mrs. Noble had died in 1899 after a married life of forty-eight years. One son survives him.

Admiral Sir Erasmus Ommanney, K.C.B., was born on the 22nd of May 1814. He entered the Navy at the age of twelve, and assisted at the landing of the British Army at Lisbon in 1827, and served as a midshipman on board the *Albion*, the flag-ship of his uncle, Sir John Acworth Ommanney, in the battle of Navarino. In 1835 he served as lieutenant with Captain (afterwards Sir James) Ross in an expedition to relieve whaling vessels ice-bound in Baffin's Bay. In 1840 he was appointed to the command of the steam sloop *Vesuvius*, and was actively employed in the Mediterranean for several years. In 1850 Captain Ommanney served as second in command under Captain Austin in an expedition sent by the Admiralty to discover the fate of Sir John Franklin. He travelled in sledges over five hundred miles, being away from his ship for sixty days, and discovered that Franklin and his companions had spent their first winter on Beechey Island. Shortly after his return to England the Crimean war broke out, and he was given command of the White Sea Squadron, which bombarded Archangel and other ports. He was promoted to be rear-admiral in 1864, when his active service with the fleet ceased. In 1875 he retired under the age limit.

Admiral Ommanney's most important scientific work was the geographical information he obtained in his Arctic explorations. He was one of the oldest members of the Royal Geographical Society. He was elected a Fellow of the Royal Society in 1868. He served on the Council of the British Association, and was treasurer in 1884 on the occasion of the visit to Canada. In 1885 an honorary LL.D. was conferred upon him by the University of Montreal.

Sir Erasmus Ommanney was one of the oldest Fellows of the Royal Astronomical Society, having been elected on the 14th of

January 1853. During his long connexion with the Society he had the good fortune to witness several of the most interesting astronomical phenomena of last century. In 1866 he observed the shower of *Leonid* meteors, and sent a brief description to the Society. He observed the transit of *Venus* at Luxor on the 12th of December 1874, Sir William Abney and Dr. Auwers being at the same station. A short account of an aurora borealis seen at Ilfracombe, given by him in the *Monthly Notices* for November 1870, is interesting from the remark: "During all my Arctic voyaging I never witnessed in any aurora the same conditions of varied colouring as were displayed on this occasion."

Admiral Ommanney died on the 21st of December 1904 at the residence of his son, St. Michael's Vicarage, Portsmouth.

William Montgomery Pierson, of San Francisco, was a lawyer of prominence in California. He was born in 1842, and after receiving the ordinary education of the State schools was admitted to practise law before he attained his majority, a special Act of the State Legislature being passed expressly for the purpose. He became law partner of Henry H. Haight, afterwards Governor of California. Notwithstanding an active business life, he found time to devote to astronomy, and was well known on the Pacific coast as an excellent amateur astronomer. He took a prominent part in the formation of the Astronomical Society of the Pacific, and was chosen as Vice-President, succeeding Dr. Holden as President. Till his death he remained on the Board of Directors, the Finance and Comet Medal Committees. He fitted out at his own expense an expedition to observe the total solar eclipse in India in 1898. This expedition was directed by Professor Burckhalter, who used a rotating occulting plate to obtain an exposure of suitable length in different parts of the corona. In 1903 he presented his 8-inch reflector to the University of California. His loss was deeply felt by many American astronomers belonging to the Astronomical Society of the Pacific. He died in November 1904. Mr. Pierson was elected a Fellow of the Society on the 9th of January 1891.

Eyre Burton Powell, M.A., C.S.I., was for many years Director of Public Instruction in the Madras Presidency. He was one of the oldest Fellows of the Society, being elected on the 13th of January 1854. He had a small refractor in the grounds of the Government Native College at Madras, and frequently observed comets, double stars, &c., working in co-operation with Captain Jacob, the Hon. East India Company's Astronomer. His first contribution to the Society's publications is in 1854, when he communicated a series of observations of Comet II. of that year and a determination of its elements, and pointed out that these agreed with those of a comet observed in 1677 by Hevelius. In 1856 he forwarded to the Society his observations of 130 double stars made in the years 1853–4–5. These are published in vol.

xxv. of the *Memoirs*. As he had not a clockwork movement and his instrument was not a powerful one, he confined himself wholly to the observation of position-angles. From 1853–61 he made observations of the nebula round η *Argûs*, and of the variation in the brightness of η *Argûs* itself. Observations of double stars made by him at Madras in the years 1859–62 are given in vol. xxxii. of the *Memoirs*, and his observations of later date are to be found in *Monthly Notices* for November 1883. He also contributed several computations of the orbit of α *Centauri*, the first being in 1854 and the last in 1892.

Mr. Powell died at his residence at Streatham on the 10th of November 1904 at the age of 85 years.

Dr. Walter John Bruce Richards was a distinguished priest of the Roman Catholic Church and an intimate friend of Cardinal Manning and Cardinal Vaughan. Born in 1835, he was ordained priest in 1859, and was in 1870 appointed by Cardinal Manning Diocesan Inspector of Schools. The main work of his life was educational, and his duties brought him into frequent contact with educationalists outside his own communion. He was chosen to serve on a Royal Commission on Poor Laws and Industrial Schools.

Dr. Richards's interest in astronomy was especially in the field of selenography. He was one of the original members of the Selenographical Society and a contributor to its *Journal*, which was issued from 1878 to 1882. The *Journal* was discontinued, and the Society practically came to an end when Mr. Neison (Nevill) left England for Natal. Dr. Richards also contributed monthly articles on lunar work to the *Astronomical Register* from 1881 to 1883, containing notes on lunar formations and suggestions for observation.

He was elected a Fellow of the Royal Astronomical Society on the 11th of February 1876. He died in September 1904.

Isaac Roberts was born at Groes, near Denbigh, North Wales, on the 27th of January 1829; before his childhood was over, however, the family removed to Liverpool, and in that city the greater part of his long life was spent. His parents were not well to do, his father being a farmer, and later a bookkeeper; and after receiving an elementary education he was set to work in the building trade: in this he prospered greatly, becoming ultimately a partner in a large firm of contractors, with ample means for the prosecution of his scientific researches.

His taste for these was shown in early days when as a builder's apprentice he attended evening courses on scientific subjects; but he had entered his fiftieth year before his first astronomical telescope was mounted. This was a 7-inch refractor, and was followed by a reflector of 20 inches aperture and 98 inches focal length for photographic purposes: the two telescopes were mounted on the same declination axis and were moved

in R.A. by the same clock, but had independent move-
declination. With this arrangement the whole of Dr.
work in celestial photography was done, first at Maghull,
erpool, and since 1890 at Crowborough, in Sussex. He
ich labour in devising an instrument for copying the
f stars from the photographic film and engraving them
per plate: an account of this instrument, which was
pantograver, will be found in *Monthly Notices*, vol. xlix.
Roberts's first programme of astronomical research was
ation of a photographic chart of the northern heavens.
k was actually commenced, but was abandoned when
me for an international astrographic chart was ap-
After this he applied himself to the photography of
ters and nebulæ, achieving a most remarkable success
ng greatly to our knowledge of these objects. In 1893
a volume of reproductions of photographs of stars and
nd this was followed by a second collection six years

ecame a Fellow of the Royal Astronomical Society in
of the Royal Society in 1890. In 1892 the degree of
s conferred on him by Dublin University, and in 1895
ed the gold medal of the Royal Astronomical Society for

being a vigorous opponent of the recent Education Acts. Under the terms of his will large bequests are made to Liverpool University and the University Colleges of North and South Wales.

Maurice Allen Smelt was born in 1821. He went to Gonville and Caius College, Cambridge, and took his degree in 1842. He was ordained deacon in 1843, and after holding curacies in Kent and Hampshire was appointed Rector of Medstead, Hants, from 1863–67. He retired to Cheltenham, and gave ready assistance to religious and philanthropic societies. In particular he was for twenty years honorary secretary to the Cheltenham and Gloucester Society for the Care of the Blind. He took an interest in several branches of science, especially astronomy and meteorology. He became a Fellow of the Royal Astronomical Society on the 8th of March 1861.

Mr. Smelt died on the 6th of December 1904 at the age of 84 years.

Captain John Steele was born in 1819. He went to sea in 1834, and served a somewhat rough apprenticeship in the merchant service. He remained at sea for thirty-eight years, during thirty-three of which he was in command, most of the time in sailing ships. He was employed in transport service at Balaclava during the Crimean war, and after that time made frequent journeys to China and Japan. In 1872 he was appointed Nautical Assessor to the Board of Trade, and in 1878 Examiner in Seamanship and Secretary to the Local Marine Board, a post he held till 1897. He was one of the founders of H.M.S. *Worcester* Nautical School, and was a member of its committee till his death. Captain Steele throughout his whole life used his influence consistently towards improving the condition and tone of the merchant service. Captain Steele was a Fellow of the Royal Meteorological Society and for twenty-eight years kept records at sea for that Society. He became a Fellow of the Royal Astronomical Society on the 13th of February 1880. He frequently attended and occasionally spoke at the meetings, but did not contribute to the publications of the Society.

Captain Steele married twice. He died on the 19th of April 1904, and leaves a widow and a daughter.

Sir Henry Thompson was born at Framlingham, in Suffolk, on the 6th of August 1820. In accordance with his father's wishes, though contrary to his own, he was engaged till he was twenty-seven years old in commercial pursuits. In the year 1848 he entered University College Hospital, where his surgical skill and deep interest in his profession were immediately conspicuous. In 1853 he was appointed Assistant-Surgeon to the hospital, and in 1866 Professor of Clinical Surgery. His reputation as a skilful surgeon was so great that in 1863 he was consulted by

g of the Belgians, when his accurate diagnosis and suc-
operation brought him professional renown. Along with
practice and his duties at University College, Sir Henry
on found time to develop his marked talent for art and
re. He studied painting under Elmore and Alma-Tadema,
quently his pictures were exhibited at the Academy or
is Salon. He wrote several novels, the first, *Charley
n's Aunt*, had no fewer than fifteen editions. His profes-
ritings were numerous, and mention may be made of some
are of general interest. His article in the *Quarterly*
years ago advocating Cremation led to its adoption
and; and Sir Henry Thompson was President of the
on Society till his death. His books *On Food and Feeding
t in Relation to Age and Activity* went through many
. At the age of eighty he became an enthusiastic auto-
, and in 1902 wrote a small book on the motor car.
Henry Thompson's interest in astronomy led him to build
rvatory at his country house at Molesey. Messrs. Cooke
for him in 1887 an equatorial with a visual object glass of
s and a photographic object glass of 8 inches aperture. With
g spectroscope attached to this equatorial he and his assist-
A. Taylor, made observations of widened lines and other

the Pulkowa Observatory, in succession to Otto Struve—a position from which he retired in a few years—and a member of the St. Petersburg Academy. Most of his subsequent papers have been published in the *Bulletin* of the Academy. A systematic exposition of Bredichin's work on comets has been written by R. Jaegermann. Many of his other papers refer to meteors, meteor streams, and stationary radiants. In 1884 he was elected an Associate of the Royal Astronomical Society.

His death occurred, after a short illness, on the 14th of May 1904.

Paul Henry was born at Nancy on the 21st of August 1848, and died at Paris on the 4th of January 1905. His younger brother Prosper, in collaboration with whom all his astronomical work was done, died on the 25th of July 1903. In the Report of the Council for last year an account is given of the work of the brothers Henry, and it was stated that it was not possible to separate the work of Prosper Henry from that of his brother Paul. A more detailed notice of the work of MM. Henry will be found in that report. Appointed Assistant Astronomers at the Paris Observatory in 1868, they set themselves to complete Chacornac's Charts of the Ecliptic. As they approached the Milky Way the large number of stars made visual observation almost impossible, and they tried photography The results they obtained, presented by Admiral Mouchez to the Academy in August 1884, were so satisfactory that they commenced the construction of a 12·8-inch photographic object-glass. This realised all their expectations, and they found that a field of 3° in diameter was sharply covered, and that with an hour's exposure stars of the 14th and 15th magnitudes were shown. In the course of a few years the international photographic chart of the heavens was commenced with instruments of the pattern first constructed by MM. Henry.

M. Paul Henry was a Chevalier of the Legion of Honour and Officer of Public Instruction. He was elected an Associate of the Royal Astronomical Society on the 8th of November 1899.

PROCEEDINGS OF OBSERVATORIES.

Royal Observatory, Greenwich.
or, Sir William Christie, K.C.B., Astronomer-Royal.)

sit Circle.—During the year 13,549 observations of
and 12,309 of meridian zenith distances were obtained.
clude about 8400 observations of stars within 26° of the
ing about 5000 observations to be obtained this year
ete five observations of each star in the Catalogue. The
been observed 163 times and the Moon 89 times. Re-

meridian observations of the Moon have been obtained throughout the first and last quarters, when the Moon cannot be observed on the meridian or would be observed in a bright sky. The total number of extra-meridian observations obtained of the Moon is 63—35 near the beginning and 28 near the end of the lunation.

Reflex Zenith Tube.—During the year 817 double observations and 70 single were secured. Observations of the brighter stars have been made over as long periods as possible. γ *Draconis* has been observed 78 times, β *Draconis* 44 times, ι^2 *Cygni* 41 times, and θ *Ursæ Majoris* 29 times.

Equatorials.—A hundred and nine observations of occultations of stars by the Moon have been made. These consist of observations by one or more observers of forty-six phenomena of disappearance or re-appearance.

28-inch Refractor.—The weather has been even more unfavourable than in 1903 for the observation of close and difficult double-stars, as may be seen from the following statement of the year's work :—

Month.	No. of Nights on which Observations were made.	No. of Good Nights.	No. of Stars Observed.	Month.	No. of Nights on which Observations were made.	No. of Good Nights.	No. of Stars Observed.
Jan	8	0	36	July	15	5	163
Feb.	10	1	54	Aug.	12	2	116
Mar.	11	2	80	Sept.	9	2	74
Apr.	10	4	120	Oct.	8	0	69
May	11	3	71	Nov.	7	1	73
June	10	5	107	Dec.	5	1	69
				Totals for year	116	26	1032

An analysis of the observations gives :

76	stars of	distance	$< 0''.5$
85	,,	,,	$0''.5 - 1''.0$
127	,,	,,	$1''.0 - 2''.0$
372	,,	,,	$> 2''.0$

Amongst the stars observed are *Sirius* (once), *Procyon* (3 nights), κ *Pegasi* (7 nights), and δ *Equulei* (11 nights).

Thompson Equatorial.—With the 26-inch refractor 59 photographs of *Neptune* and satellite have been obtained on 28 nights, of which 41, belonging to the opposition 1903–4, have been measured. With the 30-inch reflector 178 photographs (generally four exposures on each) of 60 minor planets have been obtained. Comet *a*, 1904 (Brooks), was photographed on 58 nights, 76 photographs, each with several exposures, being obtained. Encke's Comet was attempted on several nights, but owing to unfavourable weather only one successful photograph was obtained. A few photographs of nebulæ were also taken.

ographic Equatorial.—During the year 200 photographs
ken on 86 nights. These include 103 successful chart
nore suitable for reproduction than those already obtained,
logue plates, 8 photographs of suspected variables, and
es rejected mainly owing to photographic defects in the
r to their not reaching the required standard in showing
ars. During the year 108 plates have been measured, and
asurement has now been carried to within 3° of the pole.
mber of plates left to be measured is 28. Vol. i. of the
aphic Catalogue, containing the measures from Dec. 64°–72°,
blished in the spring. The printing of Vol. ii. is being
on continuously, Zones 72°, 73°, and 74° to 12^h having
through the press. The counting of the stars on the
lates has been continued from Dec. 71° to Dec. 73°.
publication of the Greenwich section of the Astrographic
y means of enlarged photographic prints was commenced
beginning of May, the three Zones 65°, 66°, and 67°
tes) being taken in hand. Up to the middle of December
arged prints from 116 plates (12^h to 24^h) had been dis-
l to about fifty observatories and other institutions. It
ted that the publication for these three Zones will be
ed in about twelve months from the time of commence-

shortly. The measurement of the Greenwich photographs had by the end of the year been carried as far as 1904 December 12, and of the Indian ones as far as 1904 October 11, and the reductions are in a very forward state. In the matter of printing, the complete proofs of the results for 1903 have been received from the printer.

The increase of solar activity during the year 1904 has been steady but not rapid, and there have been no groups of spots of at all unusual dimensions.

Observations of Meteors.—The *Perseid* meteors were well observed on four nights, the number of meteors between August 10 and 14 being 473. A fair number of *Leonids* were observed on the morning of November 15, 342 meteors being seen during the night. A summary of the observations of *Leonids* is given in *Monthly Notices*, vol. lxv. p. 154.

Longitude Observations.—The printing of the determination of the longitude Greenwich-Waterville-Canso-Montreal is finished, and copy is being prepared for the printers of the determination Paris-Greenwich made in 1902. A short notice of this determination is given in *Monthly Notices*, vol. lxv. p. 219.

Mr. Crommelin and Mr. Bryant have been appointed assistants on the new establishment, and Mr. Davidson has been promoted to the higher grade of Established Computer.

Royal Observatory, Cape of Good Hope.
(*Director, Sir David Gill, K.C.B., H.M. Astronomer.*)

By the death of Mr. Frank McClean the Observatory has lost a most sympathetic and generous patron, whose benefactions to the establishment are too well known to need mention here.

His genuine devotion to his work, coupled with his many acts of personal kindness, has endeared him to all with whom he came in contact during his stay at the Cape in 1897, and his loss is felt by every member of the staff as that of a true and warm-hearted friend.

A very large amount of labour has been devoted during the year to work connected with the installation and determination of constants of the new transit circle.

The investigation of the errors of division for every division line on the fixed circle ($5'$ to $5'$) has been completed, and for the movable circle the error of each line marking the degrees. The observations were begun on 1903 September 28 and completed 1904 October 24: ten different observers took part in the work. The investigation involved 76,524 pointings for the fixed circle and 22,320 for the movable circle.

Four complete and independent series of investigations of pivot error were made during 1904: two clamp E and two

All the series agree with each other and with the
tained in 1903.
igation of the flexure and torsion of the axis, flexure
e and circles, constancy of the nadir under opposite
of motion from the zenith, have also been made, as
determination of the screw errors, screw value, and
tervals of the Repsold travelling wire micrometer.
operations were carried on day and night, to the
exclusion of ordinary meridian observing with the new
ircle, because it is only by such investigations and
nediate discussion that instrumental defects can be
l and remedied and a sound observing system with a
trument established.
bject-glasses of the long-focus lenses for adjusting the
rks vertically over the underground marks have now
eceived from Mr. Simms, and are in process of being

bservers have all passed through a course of training
ing by the Repsold method with the travelling wire
s to say, in the original method proposed by Dr.
n which no clockwork is employed to aid the observer.
ratus for the automatic motion of the travelling wire at

t temperature selected for balancing the electric bridge ;ulates the temperature (85° F.) has proved unnecessarily iz. 10° above that of the maximum temperature of the room.

result has been that the temperature of the air inside ı clock-case, in consequence of radiation from the outer though the space between the water tubes and the outer s a 2-inch-thick lining of felt) is always lower than that circulating water, and there are variable differences ı the readings of the thermometers near the upper and nds of the pendulum which would account for errors of 0^s·03 in daily rate.

outer chamber 8 feet square inclosing the clock case and double wooden walls, 9 inches apart, the space between lls being filled with sawdust, is now being constructed. ıperature of the air in this chamber will be automatically ned at 74° F., and thus it is believed that a nearly identity of temperature will be maintained throughout s of the inner clock-case.

ng to an unfortunate accident which occurred during sence of the regular observers the driving worm and of the Victoria telescope were damaged, and the moving of the instrument, including the polar axis and telescope ıad to be raised in order to remove the damaged sector. tor, driving worm, and slow-motion gear have been sent Ioward Grubb for alteration and repair.

instrument was in consequence only in use till August 26, s employed principally for the photography of star-spectra ırmination of motions in the line of sight. Seventy-four ectra were photographed during this period, of which have been measured and radial velocities deduced for *icis*, *a Tauri*, *a Argûs*, *a Canis Majoris*, *a Canis Minoris*, *norum*, *a Boötis*, and a_2 *Centauri*.

progress of printing the Cape Catalogue of 8560 stars graphic Zone Standards) has been provokingly slow. The r press was sent off on 1902 August 6: only 112 pages f were received during the year.

catalogue of 4360 stars, including 2798 selected zodiacal nd all stars brighter than 8·1 magnitude which are not ed in Gould's General Catalogue (excepting those in the cl. −40° to −52°, most of which are included in the atalogue for 1900), is nearly completed in manuscript.

t I. vol. xi. of the *Cape Annals*, containing a discussion Heliometer Triangulation of Southern Circumpolar Stars 2° of the South Pole, has been distributed.

t II. of the same volume, containing the results of a dis- of photographic plates covering the same region, has been through the press.

work of the old transit circle has been confined to the servations necessary to complete the catalogue of 2798

[redacted] and to a re-determination of the personal [redacted]vers depending on magnitude, besides the [redacted]ons of time. The total number of observa- [redacted]h less than usual.

[redacted]...	3658	Azimuth	81
[redacted]D.	150	Run	63
[redacted]...	59	Nadir	62
[redacted]...	89	Flexure...	2

[redacted]e reduced to the end of December 1905.
[redacted] transit circle, in addition to a large amount of [redacted] practice in the "moving wire" method of [redacted] transits have been observed (twenty contacts [redacted]mination of personal equation depending on [redacted]

[redacted] separate phenomena of occultations have been [redacted] the year—viz.:

[redacted]nces at the dark limb 10
[redacted]nces " " 5

[redacted]ncement of the discovery of a new comet by M. [redacted]Iarseilles was received on December 31, and an [redacted]as secured the same evening.
[redacted]r.—Of the major planets, 145 oppositions on 19 nights [redacted]bserved with the heliometer during the year, and [redacted]ions in connection with the triangulations of the [redacted]stars in this and other oppositions.
[redacted]ngulations of the comparison stars for *Mars*, 1901 [redacted] 1903, are now completed.
[redacted] been made connecting the [redacted]son's obser- [redacted]

The grain of the Ilford Monarch plates was found to be too coarse for the most accurate measurement of images on the Catalogue plates, and on July 21 return was made to the Ilford Rapid plates.

During the year 1904, 183 Catalogue plates, containing 117,073 stars, have been measured in reversed positions of each plate—including 2157 standard stars, each of the latter being measured in reversed positions of the plate by both the measurers employed on each plate. Eleven plates measured in former years have since been rejected. The actual state of the work is as follows :—

No. of Plates Measured.			No. of Plates Copied for Press.		
Before 1904.	During 1904.	Outstanding.	Before 1904.	During 1904.	Outstanding.
577	183	752	302	108	1112

The total number of measured plates is now 760, containing over 440,000 stars.

Telegraphic signals were exchanged with Major O'Shee, R.A., of the Anglo-Portuguese Boundary Commission, on April 22, 26, and 28. The observations were reduced at the Cape, and the resulting longitude of the observing pillar at Tete—viz. $2^h\ 14^m\ 21^s{\cdot}04$—has been communicated to the Colonial Office.

Major Watherston, R.E., C.M.G., arrived at the Observatory on November 22, and during his stay until December 14 practised observing with the 14-inch altazimuth, and, as a first step in the determination of the longitude of Accra, on the West Coast of Africa, made with Mr. Pett a very satisfactory determination of his personal equation in time determination and in sending and receiving submarine mirror signals.

The records of the seismograph have been regularly forwarded to Professor Milne, Secretary to the Seismological Committee of the British Association.

The meteorological observations made during 1903 have been communicated to the Cape Meteorological Commission.

H.M. Astronomer was absent on leave from March 26 to October 25. During his visit to England he attended the Congress of the International Association of Scientific Academies as a delegate of the Royal Society, and was also much occupied with preliminary arrangements in connexion with the approaching visit of the British Association to South Africa in August 1905.

Geodetic Survey of South Africa.
(Report from Sir David Gill.)

The work of the Geodetic Survey in the Transvaal and Orange River Colony has been energetically pushed on under Colonel Morris.

The whole of the reconnaissance of the principal chains of triangulation, about 2200 miles in length, has been completed,

exception of 360 miles, which have been discarded as
lutely necessary.
beaconing of all points, 125 in number, of the primary
as been completed, leaving only 47 points of a secondary
m Ottoshoop to Kimberley to be beaconed. The base
Kroonstad and Houts River (some thirty miles north of
rg) have been measured.
angles of the whole chain from Newcastle in Natal
Belfast to Ottoshoop (435 miles in length, containing
s, including four base terminals) have been measured.
angles of another chain from Pretoria southwards through
nd to Cala in the Cape Colony have reached the neigh-
l of Lindley in the Orange River Colony: the work
ers 160 miles of chain, containing 16 points, including
terminals.
lling operations from M. S. L. at Lorenzo Marques have
rried along the railway to Melalane (86 miles); the
of the remainder of this line (107 miles) to Machadodorp
left for execution next winter. From Machadodorp
of levelling has been carried a further 136 miles—that
in twenty miles of Pretoria. The total amount of

These probable errors of the total length of the base are derived from the differences of the three independent measures of each section, and include therefore all the effects of the accidental errors of measurement with the Jäderin wires as well as the accidental errors of the different measurements of the standard base, but not the systematic errors due to the determination of the absolute length of the steel bars of the geodetic base apparatus.

The accuracy attainable with the Jäderin method and the employment of *invar* wires is thus all that can be desired.

Up to the present time the computations include the closure of fifty-seven triangles. The errors range as follows :—

	0″·0 to 0·5	0″·5 to 1·0	1″·0 to 1·5	1″·5 to 2·0	2″·0 to 2·5
Newcastle-Belfast	10	4	3	0	1
Neighbourhood of Belfast...	8	5	4	1	2
Belfast to Ottoshoop ...	13	4	1	0	1
	31	13	8	1	4

The probable error of the levelling operations appears to be about 1 inch per 100 miles.

The difference between the length of the side (Salt Lake-Inkwelo) in the north of Natal, as found on the one hand from the Natal base and on the other from the Belfast base, is 1·46 foot in 30·7 miles, or about 1 : 100,000 ; an agreement which appears to indicate that these two independent systems of triangulation—the one depending on short base lines measured with the steel bars and the other on long base lines measured with nickel steel wires—are in substantial agreement.

As mentioned in last report, progress with the arc of meridian, north of the Zambesi, had been very much hindered by grass fires, and any but astronomical observations for latitude at Msambamsou and for latitude and azimuth at Kawira had been impossible. Dr. Rubin was in consequence instructed to demarcate the Portuguese boundary running due south from the Zambesi near Zumbo, and to fix the point where the 15th parallel of latitude crosses the river Loangwa. This work, together with that of reconnaissance and beaconing, occupied Dr. Rubin and his party till April 1904, since which time the points Tondongwe, Inyangan, and Msambamsou have been occupied for the measurement of horizontal and vertical angles and astronomical latitude determined at Kapsuka. No report of work after June 30 has yet been received from Dr. Rubin.

Royal Observatory, Edinburgh.
ector, Dr. Copeland, Astronomer Royal for Scotland.)

meridian observations made during 1904 have been l for the most part to the same programme as for ears past—viz. the zodiacal stars and heliometer com-tars of Sir David Gill's lists and the clock-star list of *ner Jahrbuch*. The total number of observations, all of ave been made by Mr. G. Clark, is somewhat less than ge of several years past; a result which is to be attributed ong-continued periods of cloudy weather experienced in r half of the year. During the past four months only o nights could be classed as good observing nights, everal of these observations were possible only for an so. In the same period about 50 per cent. of the nights npletely overcast. Of the observations secured, 305 clock-stars, 714 of zodiacal stars, 71 of azimuth-stars, of the planets *Juno*, *Neptune*, *Saturn*, and *Jupiter*, a total of 1111. All of these observations, with the n of a few of the clock-stars, included measures of right

which will appear in future numbers of the *Transactions* and *Proceedings* of the Society.

The 24-inch reflecting telescope has recently been equipped with a photographic plate carrier, designed by Mr. Heath and constructed by Mr. J. B. McPherson, engineer to the Observatory. It is provided with two slow-motion screws for moving the plate and guiding eyepiece in two directions at right angles to one another.

Several attempts were made by Mr. Clark to observe Encke's Comet, and comets 1904 *d* and 1904 *e*, with the 15-inch equatorial, but unfortunately without success, clouds or bright moonlight having on every occasion interfered with the observations.

Seismographical observations are made continuously and reported to the Seismological Committee of the British Association.

The Observatory supplies Greenwich mean time to Edinburgh and Dundee daily.

Meteorological observations are made continuously.

Cambridge Observatory (Director, Sir R. S. Ball).

Reduction of Photographs of Eros.—The reduction of a series of photographs of *Eros*, taken at nine observatories during the period 1900 November 7–15, was completed in June 1904, and a summary of the results communicated to the Society by Mr. Hinks (*Monthly Notices*, vol. lxiv. p. 701). The value of the solar parallax deduced from 295 exposures was $8''\cdot797 \pm 0''\cdot0047$. There is evidence of an oscillation in the place of the planet with a semi-amplitude of $0''\cdot03$ and a period of $2^h\ 38^m$, half the complete period of variation of light.

Since July good progress has been made with an investigation of systematic differences between the published results of different observatories and in the formation of a standard system of comparison stars for the whole extent of the observations.

Twenty-three exposures to complete the Cambridge contribution of 112 exposures to the above-mentioned investigation were measured in January by Mr. Hinks, who has had the help in computation of Miss Bell and Miss Malden.

Meridian Circle.—The alterations and additions to the meridian circle mentioned in the last report were completed by Messrs. Troughton & Simms in April. During the summer the instrument was completely adjusted and reduced to a condition of steadiness, and the observation of Sir David Gill's Zodiacal Star Catalogue was resumed on September 15, since which date about 700 observations have been made by Mr. Hartley.

The observations for the second list of heliometer comparison stars have been sent to Sir David Gill.

epshanks Equatorial.—Good progress has been mad
servation of the objects in the stellar parallax w
epared in 1903. During the year 177 successful
een taken by Mr. Russell and 32 by Mr. Hink
r of exposures on each plate is usually four. Mr. I
asured 107 plates, and the reductions are well adva

ating Zenith Telescope.—Mr. Cookson has retur
idge from the Royal Observatory, Cape of Good
removed his floating photographic zenith telescop
all dome on the main building and installed it in
g designed to avoid the effects of temperature c
wind. The instrument has been adjusted, and is r
n a determination of the aberration constant by Kü
l, and of the variation of latitude.

f-recording Meteorological Instruments.—The Dine
ng barograph mentioned in the last report was in
spring, and has been constantly compared wi
rd barometer.

e Bendorf electrograph, with radium radiator, has l
with a few interruptions, since June.

e Callendar sunshine-receiver lent by Dr. W. E.
een mounted equatorially with a new form of

friction rollers at the bottom of the polar axis of the telescope. The photographic work was not resumed till 1905 January 12. Now that every part of the mechanism has been so thoroughly overhauled, measurements are to be made and recorded of the power required to move the telescope, of the power transmitted by the clockwork, and so forth, for comparison with measurements when any future defect calls for rectification.

Provision is being made for making solar spectroscopic observations, and specially for testing the atmospheric conditions for such work at Cambridge with the large instrument. The interest in the results of this investigation has been enormously enhanced by the munificent bequest of £5000 made by the late Mr. Frank McClean, F.R.S., with the view of extending and improving the instrumental equipment of the Observatory. The preliminary work thus assumes a new aspect when it is begun with the immediate prospect of its being developed in the direction that experience may show to be desirable; and though it is our great loss that we have not now the benefit of his expert advice, it is a peculiar pleasure to have the work connected with the memory of Frank McClean—a benefactor who has shown in so many ways his desire to advance astrophysical science.

Dunsink Observatory.
(Director, Prof. C. J. Joly, Royal Astronomer of Ireland.)

The chief work during the past year consists in the reduction of the observations of the stars of Sir David Gill's zodiacal list which were made with the Pistor and Martin's meridian circle. All the stars observed have been reduced to 1900·0. The precessions and secular variations for the stars observed in 1900 have been computed, and the work of preparing the results for their final form is proceeding.

The opportunity afforded by the cessation of systematic observation with the meridian circle was utilised in having the instrument overhauled. The mirrors for the illumination were resilvered and traces of fungus were removed from the object-glass. A new reticle was also fitted. Two series of observations were made in order to determine the personal equation due to the magnitude of stars in transit. By means of a suitable series of screens the stars were observed over half the wires at full magnitude, and over the remaining half at about the eighth magnitude. The first series gave a fairly marked personal equation. As the star images during this series of observations were not particularly good, a new series was carried out after the object-glass had been readjusted. The personal equation deduced from the new set of observations was practically *nil*.

The errors of each degree division of each circle of the meridian instrument were also determined.

Three hundred and forty-seven stars were observed with the

circle during the year. Of these, 165 were observed k-error and 182 for the personal equation determi-

mber of photographs of nebulæ and star clusters were ith the Roberts equatorial. This is a reflector with a nirror and a guiding telescope. A good deal of trouble ys been experienced with this instrument owing to the y of the mirror in its cell. Frequently plates are wing to sudden displacements of the images, especially ong exposures. Some modifications were made in the ng the past year, and the performance of the instrument btedly improved. There is, however, still at times a le shift of the mirror.

measures of double stars were made with the South l with the object of testing the suitability of the instru- systematic work in this department. The imperfections iving-clock interfere seriously with the accuracy of the This instrument has, as usual, been employed on the urday of each month in showing objects of interest to

ime service to Dublin has been continued, and it has nsiderably improved by corrections for the temperature

the red and yellow region of the spectrum of *Jupiter*. The photographs confirm the existence of one dark band near C, while they contain no trace of those visually observed in the yellow.

A new sidereal clock by Riefler was installed in December.

A paper on "The Spectrum of Nova *Persei* and the Structure of its Bands as Photographed at Glasgow" has been published in the *Transactions* of the Royal Society of Edinburgh, vol. xli. Pt. II. (No. 10).

The time service and meteorological observations have been carried on as in former years.

Liverpool Observatory. (*Director, Mr. W. E. Plummer.*)

In the last Annual Report it was mentioned that it was proposed to measure some photographs made at other observatories, but that difficulty had been found in the lack of the necessary measuring apparatus. By the kindness of Professor H. H. Turner this deficiency has been supplied by the loan of a measuring machine. A plate of the *Hercules* cluster taken at the Yerkes Observatory has been measured in the past few months. The number of objects whose positions have been recorded is 2131. In the densest part of the cluster one star has been observed on an average in an area of ten square seconds. The constants of the plate have been determined, and other inquiries connected with the distribution of the stars in the cluster are now being prosecuted.

A good deal of attention has been devoted to comets, as in previous years. Many of the observations have been reduced, and these will be presented to the Society in due course. Double stars have also been observed occasionally.

The Observatory has to report no alteration in its staff or permanent equipment. The meteorological and seismological observations are continuously maintained. In connection with the routine work may be mentioned the distribution of time signals, the testing and rating of chronometers, the examination of sextants and other apparatus, for which the Mersey Docks and Harbour Board is prepared to grant certificates of test. Lectures in connection with the University of Liverpool are regularly given in the Observatory.

Radcliffe Observatory, Oxford.
(*Director, Dr. Rambaut, Radcliffe Observer.*)

During the past year very little routine work has been done with the transit circle. Occasional observations have been made for the determination of time and instrumental errors. The working parts of the instrument have been carefully tested. The condition of the micrometer screws of the microscopes and

was examined in the manner described in the Radcliffe
ions, 1886, p. xi, with the satisfactory result that no
ffect of wear could be detected. A re-determination of
ntal flexure corroborated very closely the value for this
obtained in 1902 which had been used in the reductions.
principal work in connexion with the transit circle was
ination of the errors of the pivots.

vious reports references have been made to this subject,
rto all attempts to determine these minute errors have
atisfactory. This year a novel and highly sensitive
f testing the pivots has been adopted, and the errors
n measured with a remarkable degree of precision. The
mployed and the results obtained are described in a
nmunicated to the Society and published in the *Monthly*
ol. lxv. 1, p. 56. This paper contains a table (p. 77)
e corrections necessary to the Radcliffe Catalogue for
ree them from this source of error.

rinting of the catalogue referred to in recent reports has
postponed for lack of funds, and accordingly other more
work has been allowed to interfere with the actual pre-
of the copy for press. But the material is now complete,
hoped that the copy will soon be in the printer's hands.

consultation with him. This work might have commenced at the beginning of September, but unfortunately the necessity of waiting for a special plateholder caused so much delay that it was found impossible to make a beginning until the middle of October, after which the state of the weather interfered very much with operations. Thirty-one photographs, each containing three separate exposures, have been made in connexion with this work, of which twenty-one have been carefully stored away undeveloped in tin boxes to be exposed again during the spring months, and finally once more in the following autumn, so as to obtain, in close juxtaposition on the plate, images of the stars at each of three successive maxima of parallax, in accordance with Professor Kapteyn's scheme.

Early in June a machine of a novel pattern for measuring photographs was supplied by Sir Howard Grubb. This instrument is constructed to measure plates of any size up to 12 in. × 12 in. So far the work done with it has been confined to measures for testing the micrometer screws and examining the division errors of the scales. Until quite recently a difficulty has been experienced in getting a sufficiently accurate scale for subdividing the *réseau* intervals; but it is expected that before long a scale satisfactory in every respect may be obtained. The errors of the screws are found to be exceedingly small.

Meteorological and earth-temperature observations have been carried on as heretofore.

University Observatory, Oxford.
(Director, Prof. H. H. Turner.)

The portion of the *Astrographic Catalogue* assigned to this observatory was completed in February last in MS. The first plates were exposed in 1892 January, and the work has gone on continuously until 1904 February 17, when the reductions of the last plate were completed. During the twelve years which have elapsed since the commencement of the work much has been learnt from experience, and some of the earlier plates could be improved. But the work can be reported complete, leaving revisions and additions to be made as opportunity offers. It is hoped that funds for printing the work will soon be provided by the Government and the University jointly; but the negotiations, in which the Royal Society has rendered kind and important assistance, are still proceeding.

Attention has now been directed more particularly to the *Eros* plates, many of which have been measured. Those falling within the period 1900 November 7–15, for which Mr. Hinks of Cambridge undertook a general discussion, were measured with attention to his suggestions, and the results sent to him for incorporation with others (*Monthly Notices*, vol. lxiv. p. 701).

The stereo-comparator presented to this observatory by

L. Brook, F.R.A.S., was set up in January last, and a
f plates have been compared during the year, but with-
ng anything worthy of special notice as yet. This,
is only what might have been expected.

diting of the "Rousdon Variable Star Observations"
much of the time of the Director during the early part of
(*Memoirs R.A.S.*, vol. lv., and *Monthly Notices*, vol. lxiv.
Other investigations have been of a minor character.
he early months Dr. J. H. Metcalf, of Vermont, U.S.A.,
l his work on the measurement of plates (*Monthly*
vol. lxiv. p. 437).

Director visited the United States during the summer
xion with the St. Louis Congress of Arts and Sciences,
fully acknowledges the cordial reception he met with at
r of observatories.

ording the conclusion of the heavy piece of work on
graphic Catalogue the labours of three persons call for
cognition. Mr. F. A. Bellamy has taken practically all
s and superintended the whole work throughout with
devotion and care. It is pleasant to be able to mention
University has conferred upon him the honorary degree
in acknowledgment of these special services. Mr. B.

reduction as they are required. A positive on paper accompanies each negative, and these are mounted on cartridge paper and then bound up into half-yearly volumes, the Mauritius prints being primarily used to fill the Indian gaps. The printing from Canon Selwyn's excellent Ely negatives is now complete, and affords a fairly continuous record of the changes on the solar disc from 1863 February 9 to 1874 February 25. The total number of prints thus obtained is 1655, of which 1481 have been mounted in a similar manner to the Indian prints.

The Spectro-heliograph.—A hundred and twenty-seven days were fine enough to warrant attempts being made to obtain monochromatic photographs of the Sun. Owing to its unfavourable location the instrument can only be used between April and November, and during that period 477 "K-light" negatives of the disc and 95 of the limb and disc combined were obtained. A number of these have been enlarged to 8-inch glass positives, and experimental measures are being carried out for the purpose of finding the most satisfactory method of determining the positions and areas of the calcium vapour clouds shown thereon.

A new 12-inch photo-visual Cooke objective, of 18 feet focal length, has been in use since April 9 for focussing the solar image on the primary slit, and this has produced a marked improvement in shortening the times of exposure. A brief description of this instrument and an account of the results so far obtained are in hand and will be submitted to the Society at an early date.

Stellar Spectra.—The instruments principally used in photographing stellar spectra were the 6-inch Henry prismatic camera, with one 45° objective prism; the 2-inch calcite-quartz prismatic camera; the 9-inch prismatic reflector, with one $7\frac{1}{2}°$ objective prism; and the 36-inch reflector. Fifty-two spectra have been photographed with the first-named instrument, forty-two in the ordinary region and ten taken during focussing trials preparatory to photographing the green, F—D, region in the spectra of the brighter stars. The calcite camera has been chiefly used for photographing spectra of pairs of stars situated on the same levels, but on opposite sides, of the temperature curve based on the chemical classification, the purpose being to test the equality of temperature of such pairs. Altogether, twenty-nine negatives, including twenty-five different pairs of stars, were obtained, and besides these a number of trial exposures were made to determine the colour curves and ranges of various makes of dry plates. The spectra of fifteen of the fainter stars have been photographed with the 9-inch prismatic reflector. The pressure of other work and the delay in re-adjusting the rails, which are out of level owing to the subsidence of the concrete foundations on which they rest, have prevented any extensive employment of the 36-inch reflector; but the field of best definition has been determined, and the Hammersley 3-prism spectroscope, which is used in conjunction with this

nt, has been cleaned, adjusted, and remounted in pre-
for the photographing of the spectra of various nebulæ
tars which is now in progress.

rs.—No organised attempt was made to observe the
and *Leonid* showers of 1904, but observations made
ie intervals between routine work led the observers on
he conclusion that the former shower afforded a fairly
lay. Thirteen plates exposed in ordinary cameras by
ie observers on August 11 and 12 showed no trace of a
rail.

ratory Work.—A number of arc spectra of elements
en photographed in the region λ 4800–λ 5900 with the
Rowland grating, using the third order. The 3-inch
pectroscope has been used to obtain the arc spectra of
substances, including several mineralogical specimens
d for analysis by the Geological Survey. Researches on
ociation of gas from minerals under varying electrical
ns have been commenced and are still in progress.

elation of Solar and Meteorological Phenomena.—The
the computing staff has been largely employed in con-
the reduction and plotting of published meteorological

has suffered in the same way; there have been too many days between successive exposures, and many of the photographs are of inferior value owing to unfavourable atmospheric conditions.

The solar surface has been observed on 215 days, recorded by 213 drawings of spots and faculæ and two blank sheets.

Spectrographs of the larger spots have been taken with the grating spectrograph in the green and violet regions; and a considerable number of experiments have been made on the photography of the red end of the spectrum.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

The work of the Observatory has been resumed as in past years—viz. the observation of double stars, the phenomena of *Jupiter's* satellites, and the usual meteorological observations at 9 A.M. and 3 P.M.

Wolsingham Observatory. (*Rev. T. E. Espin.*)

The work of measuring the double stars of Herschel, and other stars which have been mostly neglected, between N. 30° and 40°, has been carried on; between thirty and forty new pairs have been detected as well. Most of these have been measured, though some of them are too difficult for the $17\frac{1}{4}$-inch. The majority of the measures have been made since August, ill health preventing night work in the earlier part of the year.

Sir William Huggins's Observatory, Upper Tulse Hill.

The photography of the spectra of stars and other celestial bodies, which has been in progress for many years, is being continued.

Experimental work in the laboratory has included, in addition to the photography of terrestrial spectra, further experiments of the radiation of radium.

Rousdon Observatory, Lyme Regis, Devon. (*Late Sir C. E. Peek's; C. Grover, Observer in Charge.*)

The building and instruments are maintained in good working order. The year has been decidedly favourable to astronomical work, and observations have been made on 141 nights. The 6·4-inch Merz-equatorial has been used in the observation of long-period variable stars, and 489 magnitude determinations

en made. Argelander's method has been followed, as he previous nineteen years. At each observation the the variable is estimated relatively to five comparison the same field of view, the mean result being assumed to agnitude on the date of observation. About twenty--period variables are under regular observation; and as hese are circumpolar in this latitude, their light-changes inuously recorded.

occultation of *Aldebaran* by the Moon on February 24 observed: the star was clear and well defined, and dis-l instantaneously at $5^h\ 53^m\ 30^s$ G.M.T. *Aldebaran* was culted in the early morning of July 9 and in bright sun-ut the star was beautifully defined and disappeared neously at $17^h\ 28^m\ 28^s$.

following occultations of stars were observed 1904 22. The disappearances at the dark limb were all neous :—

					h	m	
8 *Tauri*	magnitude	5·3	disappeared		10	1	9·9
Tauri	„	3·9	„		10	2	25·9
.M. + 15°·633	„	6·5	„		10	4	32·9

List of Photographs taken in 1904.

	Expos. m
Neb. H V. 16 Andromedæ ...	90
Neb. H I. 159 Cassiopeiæ ...	90
Cl. H VII. 42 Cassiopeiæ ...	60
Neb. H I. 108 Piscium	90
Cl. M. 103 Cassiopeiæ	60
Cl. H VI. 31 Cassiopeiæ ...	60
Neb. Index Cat. 155 Cassiopeiæ	90
Neb. N.G.C. 674 Arietis ...	90
Cl. M 34 Persei	60
Neb. N.G.C. 1170 Arietis ...	90
Neb. H IV. 17 Eridani	90
Neb. Index Cat. 348 Persei ...	90
Neb. N.G.C. 1499 Persei	2ʰ 30
Cl. H VII. 60 Persei	60
Cl. H VII. 61 Persei	60
Neb. H I. 158 Eridani	54
Neb. H II. 289 Leporis	90
Cl. M 38 Aurigæ	90
Cl. M 36 Aurigæ	90
Neb. Index Cat. 430 Orionis ...	90
Cl. M 37 Aurigæ	90
Neb. *h* 373 Monocerotis	90
Neb. H IV. 20 Monocerotis ...	90
Cl. H VI. 2 Geminorum ...	60
Cl. M 50 Monocerotis	90
Cl. H VIII. 11 Geminorum ...	30
Neb. H IV. 45 Geminorum ...	30
Neb. H I. 218 Lyncis	90
Cl. H VI. 1 Geminorum ...	60
Cl. M 46 Argûs	90
Cl. M 47 Argûs	60
Cl. H VI. 37 Argûs	*50
Neb. H II. 908 Ursæ Majoris ...	90
Neb. H V. 26 Leonis Minoris ...	90
Neb. H V. 23 Ursæ Majoris ...	*88
Neb. H I. 79 Ursæ Majoris ...	90
Neb. H II. 81 Leonis	90
Neb. H II. 50 Leonis	90
Neb. H II. 30 Leonis	90
Neb. H II. 160 Leonis	90
Groombridge 1830 Ursæ Majoris	15
Neb. H II. 162 Virginis ...	90
Neb. H II. 132 Virginis ...	90
Neb. H I. 95 Comæ	90
Neb. H II. 749 Canum Venat. ...	90
Neb. H I. 83 Comæ	90
Neb. H I. 124–5 Virginis ...	*70
Neb. H II. 95 Virginis	90
Neb. M 94 Canum Venat (2) ...	30
Neb. H I. 162 Virginis	90
Neb. H V. 3 Virginis	90
Neb. H II. 664 Canum Venat. ...	90
Neb. H II. 691 Boötis	90
Cl. H VI. 9 Boötis	60
Neb. H II. 650 Boötis	90
Cl. M 14 Ophiuchi ...	2ʰ 0
Neb. *h* 1989 Herculis	90
Neb. H II. 199 Ophiuchi ...	*70
Neb. Index Cat. 1274–5 Sagittarii	90
Neb. Index Cat. 1276 Serpentis	90
Cl. H VII. 30 Sagittarii ...	60
Neb. M 16 Clypei ...	2ʰ 0
Cl. H VI. 23 Sagittarii ...	2ʰ 0
Neb. M 57 Lyræ	20
Cl. H VIII. 13 Aquilæ	30

[Mrs. Roberts wishes it to be known that all the photographs will be carefully preserved by her at Château Rosa Bonheur, By Thomery, Seine-et-Marne, France, and will be available for reference.]

* Stopped by clouds.

Mr. Saunder's Observatory, Crowthorne, Berks.

of the Paris negatives of the Moon have now been ly measured, the results prepared for publication and icated to the Society. In all, 2302 measures have been 1433 points. Of these, 38 points have been measured our plates, and from these it has been deduced that us of the Moon directed towards the Earth is about ile longer than the polar radius. Not much reliance is pon the absolute value obtained, but the result of the tion shows that with further measures a satisfactory ay be expected, and that the elongation is small.

purposed to measure next two of Mr. Ritchey's negatives th the Yerkes 40-inch. In a preliminary examination f these a small unrecorded crater was noticed on the *Ptolemæus*, a formation which has been kept under close tion with the telescope for some years. Its existence e been verified, but it is, even under favourable condi- difficult object in a 7-inch refractor, and its detection on tograph affords another proof of the great advances chey has made.

The time service is continued, but the time of the meridian eight hours east of Greenwich has been adopted. In 1902 the number of transits observed was 2842, in 1903 1067, and in 1904 1414. The observations of transits of southern stars were finished in July 1904, and a catalogue of over 2000 southern stars is in the press. It depends upon about 16,000 transits. The probable error of a right ascension determined from eight transits reduced to the equator is $\pm 0^{s}{\cdot}011$. Stars of the sixth magnitude and brighter stars were screened so as to appear of about magnitude $6\frac{1}{2}$ or 7, which is about the magnitude of the greatest number of stars observed. The light-equation, if any, is therefore very small. The magnitudes were carefully estimated as often as possible, and a table of corrections was constructed for reducing the recorded magnitudes to the S.M.P. The probable error of an observed magnitude is 0·2 on the S.M.P. scale. As many of them were observed eight times in the course of the six years, the results are just as accurate as those determined photometrically. Possibly magnitudes directly estimated are even better than those obtained by aid of photometers, but the latter are required for settling a fixed scale.

About 500 micrometrical measurements of double stars, mostly southern pairs, were made at Hong Kong, and nearly double that number at the University Observatory, Copenhagen, where the Director spent about a year during his leave of absence from Hong Kong.

The recalculation of the orbits of double stars has been continued and new orbits of *Castor*, ζ *Sagittarii*, ξ *Boötis*, β 416, ϕ *Ursæ Majoris*, 99 *Herculis* = A.C. 15, and *Sirius* have been published in the *Astronomische Nachrichten*, where also papers on the distribution of double stars and on the accuracy of the Markree observations of double stars have been printed. In the former paper the preponderance of binaries in certain hours of right ascension has been pointed out; in the latter the systematic errors are proved to depend upon the definition and steadiness of the images.

The fourth edition of *The Law of Storms in the Eastern Seas* has been printed. Twenty annual volumes have been issued; and as they now contain investigations of typhoons, climate, &c., as complete as can be carried out with the instrumental outfit at this observatory, it is intended to discontinue this series.

Kodaikánal and Madras Observatories.
(*Director, Prof. C. Michie Smith.*)

The year was, on the whole, a very favourable one for observations, and at Kodaikánal there were only twenty-two days on which no solar observations were possible. Photographs of the Sun were taken with the Dallmeyer photoheliograph on 264 days, and could have been taken on more had it not been

of suitable plates early in the year. Sun-spots were visually on 344 days, and sketches were made of details. In all, 236 new groups were observed during The smallest number of new groups appearing in any was eleven in February and, the largest, twenty-nine ber. The mean daily number of groups visible varied n February to 5·0 in December.

ot spectra were observed on 227 days, and attention not only to widened lines, but also to the behaviour en and helium lines in and near spots.

nences were observed on 251 days, but on twenty-one was not possible to complete the work before clouds All prominences are sketched and the heights of the ortant ones are measured. Rapidly changing promi- e followed for some time and repeated sketches are he spectra of a number of eruptive prominences have studied.

pectroheliograph, made for the Observatory by the e Scientific Instrument Company, was received in nd was brought into regular use in October as soon as ngs for it were sufficiently advanced to permit of the of covering the siderostat being moved. Since then it

reduction of those plates. The total number of these standard stars now completely observed three times or more is 4912.

Astrophotographic Work.—The following table shows the number of regions photographed :—

	Passed as Satisfactory.	Rejected.	Total Number passed as Satisfactory.
Chart plates with triple exposure of 30^m each	110	4	482
Catalogue plates, second series ...	56	3	291
Test plates on South Polar Regions	30	—	—
Test plates on Oxford Type Charts	9	—	—
Plates for trails, adjustment of focus, centre, &c.	27	—	—

The photographic record of the variation of the magnetic elements, of meteorological elements, and earth tremors has been continued throughout the year without interruption.

The usual routine work in connection with the various services required by the public, as—

Time service,
Weather service,
Registration of tides,
Rating chronometers,
Testing of instruments,
Verification of standard weights and measures &c.—

have been carried out as in former years.

Sydney Observatory.
(Mr. H. A. Lenehan, Acting Government Astronomer.)

In January the Public Service Board separated the work of the departments of the Observatory, the meteorological branch of the work, heretofore carried on under the direction of Mr. Russell in conjunction with the astronomical work, was put under the charge of the first meteorological assistant, Mr. H. A. Hunt, and the astronomical portion under Mr. H. A. Lenehan, who had the full control of the two departments under his guidance. This arrangement will terminate on 1905 February 28, when Mr. Russell will retire from the service.

Early in the year Professor Otto Klotz, the Government Astronomer of Ottawa, Canada, visited Sydney in connexion with the latitude and longitude of the stations of the Pacific Cable route to Australia and New Zealand, and determined the difference of longitude between Sydney and Southport (Queensland), and the differences between Wellington and the terminal station at Doubtless Bay (New Zealand), Sydney having pre-

letermined the longitude of Wellington. Professor
o took observations at Sydney for personal equation.
in the year Dr. O. Hecker, of the International
Association, visited this Observatory. His mission was
nine the gravity of the Earth at various stations
ut the world : this he expects to complete by the end of
ext. He also took magnetic observations for inclination
nation ; but as the electric disturbance of the city inter-
h the observations, a stone pillar was removed from the
ory to Red Hill Branch, and there cemented into
On this pier he made a successful series of observa-
h the most approved modern instruments. At the end
Dr. Hecker left for San Francisco to continue his work.
was the second place he had visited, results having
y been determined at Melbourne.
sets of time signals with Washington (U.S.A.) have
ceived, with very satisfactory results—viz. on 1904
1 and September 8, through the Pacific Cable.
irs to the floor and building at Red Hill Branch have
ried out, and new triangular wires have been placed in
7 seconds of arc apart, in the finder of the photographic
, so that three equidistant pictures can be taken.

given during the present year for printing the accumulated results now in manuscript.

The visitors' list for the year has been increased; no fewer than 1167 were shown over the Observatory, of whom 542 attended during the evenings, and on sixty occasions Mr. Lenehan gave lantern lectures and demonstrated with the equatorial. These visits took up a considerable time from the usual duties of the Observatory.

Mr. J. W. Short, astronomical photographer, gives the following results of his year's work with the Astrographic Telescope at Red Hill Branch :—

Eighty-seven chart plates, each $1\frac{1}{2}$ hour's exposure; 115 plates exposed. The preparation of a number of star lantern slides ordered by the late Minister for distribution; magnetic work which was commenced at the end of the year and other duties occupied much available time. To these and other causes the small number of plates taken is due.

Meteorology.—The number of weather charts issued was 22,100. Forecasts have been telegraphed daily to 63 stations in N.S. Wales; 4112 charts of daily rainfall and 888 monthly charts with percentages of rainfall over the State.

Climatology.—Fifty-six new stations have been established, making in all 1903, of which 1863 send monthly returns; and 40, annual returns.

Mr. W. C. Graham reports that 977 volumes have been distributed—a number considerably below that of last year, owing to delay at the Government Printing Office in completing the annual publication; 1200 volumes have been received during the year.

It is again the Director's pleasing duty to record his appreciation of the work of each officer of the staff of the Sydney Observatory, who by their industry helped in bringing the year's work to a successful issue.

Joint Report of the Government Astronomers of New South Wales and Victoria on the Measurement of the Sydney and Melbourne Plates of the Astrophotographic Catalogue.

This work is being done at the Melbourne Observatory by a special Bureau, maintained at the joint expense of the Governments of New South Wales and Victoria, as stated in previous reports.

The measurements during the whole of the year 1904 were made with the two measuring machines made by the Repsolds' on the plan of Sir David Gill, which have continued to give full satisfaction.

Mr. Russell's new measuring machine, described by him in *Monthly Notices*, vol. lxiii. page 39, has been on trial for a con-

time, but was not required for systematic use during The plates were measured in two positions, direct and nd the measures passed as satisfactory if they agreed ″·6.

lates measured are :—

90 Sydney plates, containing 44,958 stars.
64 Melbourne plates, containing 39,924 stars.

otal numbers of plates now fully measured are :—

14 Sydney plates, containing 176,019 stars.
576 Melbourne plates, containing 187,267 stars.

were unavoidable delays and interruptions in the work e year owing to changes in the staff and the training of rvers.

le Observatory, South Africa. (*Dr. Alex. W. Roberts.*)

Objects Observed.	Nights of Observation.	Number of Comparisons.
Uranus	8	95
Ceres	1	10
Hebe	13	155

Rough observations of Encke's Comet were obtained on November 30 and December 1, but it was too faint and diffused for good work.

In addition to the astronomical work, the usual meteorological observations were made during the year.

ES ON SOME POINTS CONNECTED WITH THE PROGRESS OF ASTRONOMY DURING THE PAST YEAR.

Discovery of Minor Planets in 1904.

-nine new planets were discovered, or first announced, as follows :—

Date of Discovery.	Discoverer.	Letter and Number.	Date of Discovery.	Discoverer.
1904 Jan. 10	Dugan	OC 535	1904 May 7	Dugan
" " 10	"	OD ...	" " 11	"

Letter and Number.	Date of Discovery.	Discoverer.	Letter and Number.	Date of Discovery.	Discoverer.
PF ...	1904 Oct. 16	Wolf	PM 551	1904 Oct. 16	Wolf
PG ...	" " 13	"	PN ...	" Dec. 14	"
PI ...	" " 15	"	PO 552	" Nov. 16	"
PK 549	" " 15	"	PP 553	" Dec. 14	"
PL 550	" " 16	"			

NE was discovered at Tokio; NF, OF, OH, OJ at Washington; OG at Nice; the remainder at Heidelberg.

The following planets, unnumbered at the date of the last report, have since received permanent numbers: LY 513, MB 514, ME 515, MG 516, MH 517, MO 518, MP 519, MV 520, PK 549, PL 550, PM 551, PO 552, PP 553.

The following planets do not receive permanent numbers, not having been sufficiently observed: LW, LX, LZ, MC, MD, MF, MK, MM, MN, MQ, MR, MS, MT, MU, MW, MX, MY, NE, NF, NG, NJ, NK, NL, NM, NU, NX, OB, OD, OE, OH, OJ, OP, OR, OS, OV, OX, OZ.

The following identities have been established: MZ with 409 *Aspasia*, NA with 505, NH with 200 *Dynamene*, NP with 255 *Oppavia*, OM with 236 *Honoria*, OW with 485, PE with 178 *Belisana*. The following identities are probable: OH with 353 *Ruperto-Carola*, OJ with 411, PH with 157 *Deianira*, one of the long-lost planets.

The following identities were at first suspected but negatived: NF with DW, MV with 316 *Goberta*, MY with MP, NJ with 310 *Margarita*.

The following planets have been named: 394 *Arduina*, 460 *Scania*, 496 *Gryphia*, 498 *Tokio*, 499 *Venusia*, 509 *Jolanda*, 512 *Taurinensis*, 516 *Amherstia*, 521 *Brixia*, 532 *Herculina*.

NF seems to have a very eccentric orbit, the value 0·4 being found for the eccentricity; NW was moving north at the unusual rate of 23′ daily; NY (*Herculina*) was of magnitude 9·0 at discovery, which is unusually bright for a modern discovery; NM must have been near DW in 1902, but is not identical with it; NK, NL may be a single planet, in which case it would have an interesting orbit.

433 *Eros* will be in opposition early next August in south declination 13°: its magnitude will be 11·2, the circumstances being similar to those at discovery in 1898. The *Jahrbuch* for 1907 contains an ephemeris.

Popular Astronomy for December 1904 contains an article by Mr. B. L. Newkirk on the twenty-two asteroids discovered and endowed by the late Professor Watson. The study of their orbits has been undertaken by the Berkeley Observatory under the supervision of Professor Leuschner, and it is stated that with the exception of the missing planet, 132 *Æthra*, the work is in a forward state. It is conjectured that the orbit of

a has been completely altered by the action of *Mars*, Hobe is shortly going to attempt to deduce the present is, however, difficult to see how *Æthra* could ever near enough to *Mars* to suffer large perturbations unless ed elements of the former are utterly erroneous; for, to these, the latitudes of the planets are widely t the point of approach. However, all will hope that ches may lead to the recovery of the planet, whose teresting from its large eccentricity and from the fact riod is almost exactly one-third of *Jupiter's*.

bits of planets 505, 521 approach each other within -third of a million miles, and the planets actually se approach to each other in 1903 November. It is ver, probable that their mass is great enough to cause le perturbations even at that small distance.

A. C. D. C.

Saturn's Ninth Satellite, Phœbe.

iscovery of *Phœbe* was first announced in 1899 from

evidence, not in itself convincing, but adding weight to the others, is that the observations since 1898 appear to show a *direct* motion of the node of the orbit, which would imply that the satellite moves in the opposite direction. As to the suggestion of two different satellites, it seems enough to say that the possibility of satisfying all the positions from 1898 to 1904 (except a few which had been already noted as doubtful, from their extreme faintness) by a single orbit renders very improbable the hypothesis of two different orbits related to each other in such an extraordinary manner.

Professor Berberich makes the curious suggestion in *Ast. Nach.* 3988 that the object seen in 1904 may not be a satellite of *Saturn* at all, but an asteroid whose orbit lies near *Saturn's.* This would be a reasonable suggestion if we had only a few isolated observations last year; but considering that there is a continuous series extending from April 16 to November 10, made with three different instruments—the Bruce reflector at Arequipa, the Yerkes refractor, and the Crossley reflector at Mount Hamilton—and that all the positions are in satisfactory accord with the hypothesis of elliptical motion round *Saturn*, Professor Berberich's suggestion seems quite untenable.

A perfect agreement with elliptical motion is not to be expected, for, as Professor Newcomb and others have pointed out, the solar perturbations of *Phœbe* must be very large; in particular, the evection coefficient is about 4°, which would produce a shift of over 2′ in its geocentric position. Newcomb estimates that the apse would have a retrograde movement of between ½° and 1° annually, so that this should be sensible in a few years, especially as the eccentricity of *Phœbe's* orbit is so large (about 0·22, nearly double that of *Hyperion*, which had the most eccentric orbit of any satellite previously known).

The period of *Phœbe* is 547 days, or 1½ year; its distance from *Saturn* 0·0862 in astronomical units, or 8 millions of miles. Its magnitude in opposition is probably between 15 and 16, from which its diameter is estimated as about 150 miles. Seen from *Saturn*, it would only appear as a star of the fifth or sixth magnitude, and would have a disc of about 4″ in diameter!

One explanation given of the retrograde motion is that the satellite is not an original member of the Saturnian system, but was captured later. Professor W. H. Pickering makes an alternative suggestion—viz. that originally *Saturn* rotated backwards, and that *Phœbe* was born at this period, while solar tides turned the planet over before the other satellites were born. Others had already pointed out that if the planets were formed from nebulous rings the inner portions would move quickest round the Sun, and a retrograde rotation would result. But the suggested action of the solar tides does not seem to have yet been verified mathematically, and till this is done the theory should be received with caution.

Within the last few days the announcement has been received

iscovery of a similar very distant satellite of *Jupiter.* ch for this was doubtless suggested by the discovery of If its existence is confirmed, and if its motion round should prove to be retrograde, it will undoubtedly lend of verisimilitude to Professor Pickering's hypothesis; rect, it will seriously discount it.

ny case, the discovery of *Phœbe* excites our admiration t optical triumph and adds a new and unexpected feature olar system. A. C. D. C.

The Comets of 1904.

following comets have been discovered during the year:— ks's Periodical Comet of 1889, V., seen at the Lick tory on 1903 August 20, and followed at the Washington tory till 1904 February 15.

et *a*, 1904, discovered by Mr. Brooks, of Geneva, U.S.A., 16. Particular interest attaches to this discovery, since nination of plates taken previous to the announcement earlier positions. Both Professor Pickering at Harvard Rudaux at Domville had secured places. The comet was

The comets known as D'Arrest and Winnecke passed through perihelion without being seen.

Definitive orbits of the following comets have been published during the year :—

Comet.	Character of Orbit.	Calculator.	Authority.
1845 III.	Elliptical	Peck	*Ast. Jour.* vol. xxiv.
1887 II.	Elliptical	Stechert	*Ast. Nach.* No. 3957
1889 IV.	Elliptical	Horn	*Denksch. Wien. Ak.* 74
1890 III.	Parabolic	Rheden	*Sitz. Wien. Ak.* 113
1898 X.	Elliptical	Scharbe	*Ast. Nach.* vol. clxiv.

Professor Lane Poor, continuing his researches on Brooks's Periodic Comet of 1889, 1896, 1903, has concluded that it is not identical with Lexell's Comet of 1780. W. E. P.

Progress of Meteoric Astronomy in 1904.

Quadrantids.—Very cloudy weather veiled this shower. On January 3, $12^h\ 30^m$ to $13^h\ 25^m$ G.M.T., Mr. Henry, of Dublin, counted 17 meteors, eight of which were at least equal to first-magnitude stars.

Lyrids.—Overcast skies also affected the visible return of these meteors, and few of them were seen.

Perseids.—This display was very fully and satisfactorily observed. From the whole of the reports the meteors appear to have been a little more abundant than usual, with a maximum on the morning of August 12.

Professors Perrotin and Maynard observed the shower from the summit of Mount Mounier, and on the five nights August 9–13 counted 1184 meteors, of which 941 were *Perseids.* Maximum between 13^h and 16^h August 11, horary number 92, chief radiant near γ *Persei.*

Mr. W. Wetherbee, of Barre, N.Y., on August 11, in less than 3^h, counted 154 meteors, including 116 *Perseids.*

Mr. P. M. Ryves, of Uxbridge, on August 11, between $9^h\ 45^m$ and $13^h\ 45^m$, observed 160 meteors, including 99 *Perseids.*

M. Lucien Libert, at Havre, on August 11 to 20 saw 339 meteors, and noted the motion of the *Perseid* radiant very distinctly between August 11 and 16.

Mr. A. King, Leicester, on August 11, between $10^h\ 17^m$ and $14^h\ 20^m$, observed more than 105 meteors, of which more than 80 were *Perseids.* At end of watch the horary rate was 53 and increasing. He regarded the shower as fairly rich and traced the easterly drift of the radiant.

Biesbroeck and Philippot, in Belgium, on August 10 to
ved a great number of *Perseids* and other meteors, and
he mean radiant at $45^{\circ}\cdot34+56^{\circ}\cdot47$. The comparative
r the orbit of the meteors and of Tuttle's Comet 1862 III.
puted as follow :—

Perseids.		Comet 1862 III.	
	° ′		° ′
π =	291 59	π	290 48
☊ =	138 51	☊	138 2
i	115 11	i	113 34
q	0·966	q	0·963

Denning, at Bristol, on August 11 and 12 thought the
eaker than usual ; but the observations were incomplete
veather not favourable.
shower was watched at a great many other stations,
spheric conditions being suitable and the sky moon-

At Greenwich fog began to obscure the sky after $16\frac{1}{2}^h$ November 14, so that though the maximum number of meteors was observed between $16^h\ 5^m$ and $16^h\ 10^m$ the greatest intensity of the shower may really have occurred later.

Mr. C. L. Brook, near Huddersfield, on November 14, 16^h to 18^m, counted 69 *Leonids*, of which 17 appeared in the first quarter of an hour of the watch.

Mrs. Arthur Brook at Charmouth, on November 14, 12^h to $17^h\ 30^m$, observed 144 meteors, of which about 115 were *Leonids*, and the maximum occurred between $15^h\ 50^m$ and $16^h\ 20^m$, when the rate was at least one per minute.

Mr. W. H. Pickering, at Harvard, U.S.A., reports that on November 14 three observers saw 275 meteors, including 183 *Leonids*. At about midnight the horary rate was 15 : this had risen to 134 just before 14^h, and was about 40 until 15^h, after which it was 27 for one observer. The times are Eastern Standard, and are 5^h slow on G.M.T. Only one *Leonid* was photographed at Harvard, whence Mr. Pickering concludes that only very bright or very slow meteors are capable of making an impression on the plates.

At the University of Illinois the following numbers were counted by Mr. J. Stebbins :—

	h m		h m		Leonids.	Other Meteors.
Nov. 13	13 5	to	17 5	C.S.T.	18	21
14	13 0	„	17 0	„	44	42
15	12 50	„	17 0	„	23	20

Very few *Leonids* were seen anywhere on the nights following November 13 and 15, and the maximum, such as it was, decidedly occurred on November 14; but it was not more than one-fourth the richness of the *Leonid* shower of 1903. The recent display is, however, very interesting, for the parent comet (Tempel 1866 I.) passed through perihelion in 1899. There were pretty abundant displays in 1838 and 1871, five years after the brilliant maxima in 1833 and 1866, and the *Leonids* of 1904 probably represented a return of the same group.

Andromedids.—The Rev. W. F. A. Ellison, of Enniscorthy, observed what appears to have been a well-marked return of the *Andromedids* on November 21. At 7 P.M., though the Moon was nearly full, he saw 8 meteors in 15 seconds, and during the hour from 7^h to 8^h there were 24 altogether, and from 8^h to 9^h 22 more, but few afterwards on the same night, though meteors from the same radiant continued to fall until November 28. The radiant was at about $21° + 50°$.

Geminids.—Mr. A. Sullivan, Dundrum, Dublin, observed this shower on the night of December 12, when between $10^h\ 17^m$ and $11^h\ 15^m$ G.M.T. he counted 20 *Geminids*.

ollowing is a list of the real paths of several bright bserved in England during the past year :—

.M.T.	Brightness.	Height at First. Miles.	Height at End. Miles.	Length of Path. Miles.	Velocity per Sec. Miles.	Radiant Point. α δ	Observers
h m						° °	
8 28	♃ – > ♃	60	41	27	6	41 + 5	2
8 33	♀ – > ♀	67	31	43	21	43 + 22	2
9 22	♀	63	27	36	12	*61 + 41	2
9 56	♀	66	42	42	...	*302 + 23	2
0 39	1 – ♀	75	56	33	35	46 + 58	2
2 10	> ♃	58	23	54	21	13 + 7	2
7 0½	= ♃	66	25	82	10	260 + 4	3
0 55	2½ × ♀	70	23	73	14	·344 + 24	6
6 25	> ♃	88	44	59	46	151 + 22	3
4 40	{3½ × ♀ / – = ☽}	86	40	88	...	*31 + 20	5
4 38	= ♀	81	30	64	32	*337 + 60	6
4 30	...	83	28	58	29	*330 + 36	6

· 1905 *August* 30.

The eclipse of 1905 August 30, with a path traversing Labrador, Spain, Algeria, Tunis, and Egypt, is of considerable importance owing to the fact that it is the last that will be visible from any readily accessible parts of the Earth's surface for many years. For this reason it is hoped that adequate arrangements will be made for its observation at various places along the central line.

It is also notable owing to the long interval of time—$2\frac{1}{4}$ hours—between totality at points situated towards the extreme ends of the path in Labrador and Egypt. Large scale photographs taken at the western and eastern stations should throw light upon the vexed question of the rate of change in shape of the coronal rays and streamers.

It will be remembered that in 1893, when there was a gap of $1\frac{1}{2}$ hour between totality in Brazil and in West Africa, an examination of the photographs taken with similar instruments disclosed no perceptible change of form.

Since then there has been no eclipse where pictures separated by any substantial interval of time have been secured. Moreover, on this occasion it is expected that instruments of considerable focal length will be used both in North America and in Egypt, so that the comparison of their resulting images cannot fail to be interesting.

The Joint Permanent Eclipse Committee are arranging to send five parties of observers, who will occupy stations in Spain, Algeria, and Egypt; and it is hoped that the Royal Observatory, Greenwich, will send a party to Algeria.

The proposed observations comprise an extensive programme of spectroscopic work, both with slit spectroscopes and with objective prisms of long focus and of dispersion considerably greater than have been before employed; of polariscopic work with Iceland spar prism; of determinations of the coronal radiation with a bolometer; of photographs of the corona with instruments of long and short focus, and other work.

In addition to the official parties there will doubtless be a large number of observers sent out under the auspices of the British Astronomical Association and other bodies. The facility of the journey to Spain and the fact that the eclipse falls in the summer vacation will render it easy for astronomers to take this opportunity of viewing a phenomenon which will not recur, under such favourable conditions as regards accessibility, for nearly a decade. E. H. H.

Solar Activity in 1904.

Sun-spots.—The character of the sun-spot record
y be very briefly summarised. There has been a slo
rease in the numbers and areas of spots without any
idents. There have been no days upon which the
n observed to be free from spots; there have been
ups of the first rank of importance. No single m
wn anything like the activity observed in 1903 Oct
gle group has approached that of 1903 October 5-1
t there has been a slight but steady progress throug
r, so that the mean daily area for the year is a lit
t for 1903; the figures will probably work out as a
lionths of the Sun's visible hemisphere, as against
3. This indicates an exceptionally slow advance; a
east 1000 might have been expected so long after t
m if the precedent of the two preceding cycles
owed.

Faculæ have behaved much in the same way as s
t is, they have shown a steady, persistent, but slow

being 9·0 per diem for the first half and 11·0 per diem for the second half. The total increase of 33 per cent. shown by the above figures does not, however, apply to all latitudes where prominences occur, but is chiefly confined to the equatorial zone and a zone in mid-latitudes between 30° and 40°; these zones have increased in a much greater ratio, whilst some regions in the Northern Hemisphere have actually decreased in activity.

Part of the general increase may be attributed to an advance towards the poles of the high-latitude prominences, which have thereby *reclaimed* a considerable area of the barren polar regions. These prominences now occupy the zones +55° to +65° and −55° to −70°, and these zones are still the most active regions on the Sun.

The general order of change in the prominence distribution as the sun-spot maximum is approached appears to be characterised by a great welling up of prominences in mid-latitudes, followed by an increase in the latitude of the high-latitude prominences, which seem forced by their rivals in lower latitudes to take up positions nearer to the poles. The present distribution conforms more nearly to that of 1892 than any other year since 1889.

Metallic prominences were very infrequent during the first half of the year, but later they increased considerably and reached a maximum frequency in September. On the 20th of that month the magnesium lines were strongly reversed in the upper chromosphere at almost all positions on the limb—a very unusual occurrence.

Many of the metallic prominences observed appear to be recurrences after one or more half-rotations; thus the following sequences have been observed:—

	Date.	Limb.	Latitude.	Longitude.	Period.
(1)	June 27	E	+44	285	3 rotations 27·83 days.
	Sept. 18	E	+44	267	
	19	E	+43	254	
(2)	June 27	W	−32 to −46	105	3 rotations 27·67 days.
	Sept. 18	W	−30 to −39	87	
(3)	June 29	E	−23	258	5 rotations Mean period 27·20 days.
	Sept. 4	W	−22	272	
	21	E	−22	228	
	Nov. 12	E	−24	262	

The decrease in rotation-period with decreasing latitude is here clearly indicated.

J. E.

nparison of the Features of the Earth and the Moon.

ssor N. S. Shaler, of Harvard, who commenced to study
in 1867 with the Harvard 15-inch Merz refractor, has
published in No. 1438 of the *Smithsonian Contributions
ledge* his views as a geologist on the processes by
e surface of our satellite has been moulded. He finds a
is gradation from the largest to the smallest of the ring
s, and classes them all as "vulcanoids," believing them
een formed by a non-explosive ebullition of lava. He
e theory that the rise and fall of the lava was due to
sed tides, and also the theory that the vulcanoids were
y the impact of meteorites. He, however, adopts the
the maria were formed by the impact of bolides from five
les in diameter as the only working hypothesis which
ay accounts for the phenomena. The principal moun-
es are supposed to have been formed by the exudation
viscid lava, sometimes, as in the Altai range, brought
faulting. The low ridges on the maria are caused by
n of pressure in the crust. Valleys of the Alpine type
buted to double faulting; the rills to cracks in the

Royal Observatory, Greenwich. M. N. lxvi. 8, p. 789. Measures of double stars made with the 28-inch refractor in 1903. There are 280 pairs with separation under 2″ and 150 wider pairs which include *Sirius* and *Procyon*, and 110 Struve pairs requiring recent measures.

Miller and Cogshall. A. J., p. 554. A list of stars marked double in the Albany zone 1°–5° was formed, and 38 observed with the 12-inch refractor at Kenwood.

S. W. Burnham. Decennial *Publications* of the University of Chicago. These are measures of about 600 pairs of Struve, Herschel, South, which have been neglected, and pairs discovered by various observers which do not appear to have been observed. In effect it goes far in the direction of collecting and observing the odds and ends of double stars. During the work, which was done with the 40-inch Chicago refractor, a few new pairs were found, bringing Prof. Burnham's numbers from β 1291 to β 1308.

W. J. Hussey. L. O. B. 57 and 65. Prof. Hussey has continued his systematic search for double stars, and in each of these *Bulletins* he gives 100 new pairs, so bringing his total discoveries to 800. Most of these are close and difficult, at least 30 per cent. being less than 0″·5 separation.

R. G. Aitken. L. O. B. 50, 61, and 66. These new doubles also are the result of systematic search with the 12-inch and 36-inch Lick refractors. They are similar in character to those found by Professor Hussey, at least 75 per cent. being under 2″ separation. The total number now reaches 900.

M. Biesbroeck, "Observations d'Étoiles doubles et Discussion des Mesures." These measures and their discussion are by M. Biesbroeck (Ingénieur des Ponts et Chaussées), who had the use of the 15-inch refractor at the Brussels (Uccle) Observatory. The measures of these 360 pairs were made in 1903 and 1904, and are of a high order. The complete work was done and published in eighteen months.

Calculation—

Under this heading come two papers dealing with proper motions. In the *A. S. P.* February Professor Comstock selects 67 double stars in which the proper motion of the principal component is known, and the relative motion is presumably rectilinear. This enables him to obtain proper motions for the 67 fainter comites, which he has utilised to obtain a value of the apex of the Sun's way—viz. 297° and +28°. The second paper is by Messrs. Furner and Storey in the *M. N.* 1904 March. The authors are endeavouring to find proper motions for a number of double stars, and then proceeding on the lines of Professor Comstock. Seventeen pairs are discussed and others are promised.

A. N. 3946. Herr Prey gives the masses of the components of 70 *Ophiuchi* as 0·32 and 1·28 time that of the Sun. This determination is from meridian observations, and it is to be noted

fainter companion has four times the mass of the

s computed are—

3955, Lohse —*Sirius*, period 50·38 years.
3970, Doberck—*Castor*, „ 347± „
3970, Doberck—*ζ Sagittarii*, „ 21·6 „

eous Information—

V. lxiv. 6, Plate 13. Fowler—Spectrum of Σ 2140 *lis*).

P. 99. Some nine years since Belopolsky found the fainter on of *Castor* to be a spectroscopic double with a period days. The Lick observers now find the brighter star is scopic double.

A. xiv. 7, p. 280. J. E. Gore has a note on *κ Pegasi*, for gives the hypothetical parallax as ″0·106.

. xlv. 2, p. 162. J. E. Gore discusses the relative brightness othetical parallax of 48 binaries. He concludes that the brightness decreases regularly as the stellar type of moves from A to K, and at the same time the hypo-parallax increases from ″·044 to ″·229.

vatory, No. 347. Miss A. M. Clerke discusses seven

Algol type of variation may extend to a period of many years, instead of being confined to a few days.

The publications of the observations of certain long-period variables made at the Rousdon Observatory, and inaugurated by the late Sir C. E. Peek, will be found in the *Memoirs* of this Society (vol. lv.). The material thus placed by Professor Turner at the disposal of anyone undertaking a research in this department is of great value on account of the excellence of the observations and the care with which they have been reduced.

E. E. M.

Stellar Spectroscopy in 1904.

Nebulæ.—Upon the spectroscopy of nebulæ little or no direct work has been published in 1904. Miss Clerke, however, contributes an interesting note to the *Observatory*, 1904, p. 303, on "Nebulous Double Stars," calling attention to stars involved in nebulæ.

Messrs. Frost and Adams (*Astroph. Jour.* xix. 352) have redetermined the radial velocity of the *Orion* nebula in the neighbourhood of the three brighter stars in the Trapezium; mean velocity from 11 plates +18·5 km/sec.

New Stars.—Perrine (*Lick Obs. Bulletin* 38, vol. ii. p. 130, and *Astroph. Jour.* xix. 80) describes observations made on various Novæ, and records the remarkable fact that the nebular line at λ 501 is no longer visible in Nova *Aurigæ*. Curtis (*ibid.*) records visual observations of Nova *Geminorum* and the conspicuous appearance of the green nebular line in its spectrum. Dr. Becker has published (*Trans. R.S. Edinburgh*, XLI. ii. No. 10) an account of his work on the spectrum of Nova *Persei* as photographed at Glasgow.

Classification of Stellar Spectra.—Sir Norman Lockyer, in discussing (*Proc. R.S.* **73**, 227) the "Temperature Classification of Stars," adduces new experimental evidence in the shape of photographs taken with a view of comparing the ultra-violet extensions of the spectra of various pairs of stars. The same writer has another note (*Proc. R.S.* **74**, 53) on the relation between the spectra of sun-spots and stars.

In a note read before the Section of Astrophysics at the St. Louis Congress (*Astroph. Jour.* xx. 342) Professor Frost calls attention to the desirability of arriving at some generally acceptable system of classification.

Distribution of Stellar Spectra.—The *Annals* of the Harvard College Observatory (vol. lvi. No. 1) contain a discussion of the celestial distribution of 32,197 stars according to their spectra. The work is being continued.

Studies of Special Stars.—Professor Pickering (Harv. Coll. Obs. *Circ.* 76, and *Astroph. Jour.* xix. 287) communicates a list of twenty-two stars having peculiar spectra.

H. Curtiss (*Astroph. Jour.* xx. 232) gives results (with
aphic illustrations) of preliminary studies of the spectra
uti and *W Cygni*; and also (*loc. cit.* p. 172) of *W Sagittarii*
lt's variable γ′ *Sagittarii*), with photographic illustration
spectrum.

fessor Fowler (*Proc. R.S.* lxxiii. p. 219) claims to have
ed the flutings in the spectra of stars of Secchi's Type III.
flutings sharp towards the violet and fading off towards
end of the spectrum"), with absorption corresponding to
ht flutings which he records for the first time as observed
in the spark and arc spectra of titanium, and attributed
to either titanium or titanium oxide.

N. Lockyer and Mr. Baxandall (*Proc. R.S.* lxxiv. 255)
ults of a study of enhanced lines of titanium, iron, and
m with solar lines—"Fraunhoferic spectrum" as dis-
ed from chromospheric. The same writers (*Proc. R.S.*
96) give further reasons for regarding lines λ 4089·1,
and 4116·1 (called by them Group IV. lines of silicium) as
ghtly attributed to silicium; and they support their con-
[in opposition to M. de Gramont (*C.R.* **139**, 188, and
. *Jour.* xx. 233), who attributes them to air] by reference
r spectra, a photograph of ε *Orionis* being given in com-

Messrs. Frost and Adams (publications Yerkes Obs. II. 143) have determined the radial velocities of twenty stars having spectra of the *Orion* type, and incidentally give the velocities of *a Arietis* −13·6, *a Tauri* +56·1, *a Boötis* −4·3.

Variable Radial Velocity.—The following stars have in the course of the year been found to exhibit signs of variable velocity in the line of sight:

	R.A. h m	Decl. ° ′	Mag. m		
α Andromedæ	0 3	+28 33	2·1	Lowell	Slipher, *Astroph. Jour.* xx. 146
η Piscium	1 26	+14 50	5·0	Emerson McMillin	Lord, *Astroph. Jour.* xix. 246
g Persei	1 56	+54 0	5·0	Yerkes	Frost and Adams, *Astroph. Jour.* xix. 152
20 Tauri (Maia)	3 40	+24 4	4·0	"	W. S. Adams, *Astroph. Jour.* xix. 341
ε Persei	3 51	+39 43	3·0	"	Frost and Adams, *Astroph. Jour.* xix. 152
θ_1 Orionis	5 30	− 5 29	4·8	"	Frost and Adams, *Astroph. Jour.* xix. 153
θ_2 Orionis	...	...	5·3		
σ Orionis	5 34	− 2 39	3·8	"	" "
ξ Orionis	6 6	+14 14	4·4	"	Frost and Adams, *Astroph. Jour.* xix. 154
S Monocerotis	6 36	+ 9 59	4·6	"	" "
α_2 Geminorum (Castor, bright)	7 28	+32 7	...	Lick	Campbell, *Pub. Ast. Soc. Pac.* xvi. 260
η Hydræ	8 38	+ 3 46	4·3	Yerkes	Frost and Adams, *Astroph. Jour.* xix. 155
α Libræ	14 45	−15 37	2·3	Lowell	Slipher, *Astroph. Jour.* xx. 147
σ Scorpii	16 15	−25 21	3·0	"	" "
X Sagittarii	17 41	−27 48	4·9	"	" "
W Sagittarii	17 59	−29 35	4·8–5·8	Lick	Curtiss, *Astroph. Jour.* xx. 172
Y Sagittarii	18 15	−18 54	5·8–6·6	"	Curtiss, *Astroph. Jour.* xx. 231
S Sagittæ	19 51	+16 22	5·6–6·4	"	" "
τ Vulpeculæ	20 47	+27 53	5·5–6·5	Yerkes	Frost, *Astroph. Jour.* xx. 296
ε Capricorni	21 31	−19 54	4·5	Lowell	Slipher, *Astroph. Jour.* xx. 148

Professor Frost and Mr. Adams (*Astroph. Jour.* xix. p. 356) point out that their measures of the velocity of γ *Corvi* (publica-

rkes Obs. II. 226) were made at times when the variable f it discovered by Campbell and Curtis (*Astroph. Jour.* 7) could not be inferred.

Vogel (*Astroph. Jour.* xix. 360) contributes a very in- paper on β *Aurigæ*.

	d
ring (*Sid. Mess.* 1891) gave the period of this ctroscopic binary as	3·9838
aut (*Monthly Notices* R.A.S. li. 327) deduced n the same observations a period	3·968
Maury (*Astroph. Jour.* viii. 171) in relating ervations made in 1889–1898 gave a period ...	3·9838
finds from Potsdam observations a period ...	3·9599

lso fits Tikhoff's measurements of spectrograms obtained olsky at Pulkowa. With this period all the anomalies ikhoff found, and which led him to imagine that the f β *Aurigæ* was highly complicated, disappear.

ts and Parallax of Spectroscopic Binaries.—

orbit of ι *Pegasi* (period $10^{d}\cdot2$) has been worked out by Curtis (*Astroph. Jour.* xix. 212) based on forty-three phs; range of velocity $+43$ to -52 km/sec.

Discussion of Standards of Wave-length.—The following papers relating to discussion of systems of wave-lengths have appeared :—

Messrs. Fabry and Perot	*Astroph. Jour.*	xix. 119 and xx. 318
Professor Kayser ...	„	xix. 157 „ xx. 327
„ Crew ...	„	xx. 313
„ Hartmann ...	„	xx. 41
Mr. Jewell	„	xxi. 1

New Spectrographic Installations.—Mr. Slipher (*Astroph. Jour.* xx. 1) gives an illustrated account of the spectrograph mounted in 1901 on the 24-inch refractor of the Lowell Observatory. It is being carefully used, for planetary observations in particular. The reproductions of photographs of the spectrum of *Jupiter* (*loc. cit.* Plate III.) and of *Neptune* and *Uranus* (*Lowell Obs. Bull.* No. 13) show great promise.

Professor Küstner (*Ast. Nach.* **166**, 177) began spectrographic work in the summer of 1903 with a three-prism spectrograph attached to the Bonn photographic refractor, 30 cm. (12 inches) aperture.

Mr. W. H. Wright (*Astroph. Jour.* xx. 140) reports the successful installation of the Mills expedition on the summit of Cerro San Cristobal at Santiago. With a three-prism spectrograph attached to a 94 cm. (30·7 inches) Cassegrain reflector he has detected variable radial velocity in five stars and a difference in velocity between the components of *α Centauri.*

Mr. Horace Darwin (*Astroph. Jour.* xx. 347) gives a brief description of an electric thermostat designed for the spectrograph attached to the 24-inch refractor at the Royal Observatory, Cape of Good Hope (see also *Proc. Phys. Soc. Lond.* xix. 64).

Loss of Light in Stellar Spectroscopes.—Mr. J. H. Moore (*Astroph. Jour.* xx. 285) has carried out investigations, suggested by Professor Campbell, relating to the loss of light by diffraction at a narrow slit. This paper is followed by another relating to loss of light by absorption and reflection in the 36-inch Lick objective.

H. F. N.

International Co-operation in Solar Research.

In the early part of 1904 Professor Hale drew attention to the advantages which might result from arranging some plan of co-operation among those engaged in solar investigations. At a time of sun-spot maximum in particular it is desirable that the Sun should be under almost constant observation. The subject covers a wide range, and is of a diversified character, including the observation of widened lines, photographs, and spectroheliographs. It is clear that to secure a continuous record of the spot phenomena, observations of the widened lines of all spots in a

ıble extent of the spectrum, and continuous records by
troheliograph in the H and K lines and the lines of
ı, a very extensive scheme of co-operation will be neces-
he American Academy of Sciences, which had appointed
ittee of Solar Research, with Professor Hale as chairman,
gether a conference at St. Louis on 1904 September 23.
s were sent from the astronomical and physical societies
pe and America, the Royal Society and the Royal Astro-
Society being represented by Professor Turner. The
ce passed a resolution "in favour of the organisation of
e of international co-operation in solar research which
courage individual initiative, provide suggestions for
lines of work, and facilitate the collection of results for
ion." A committee was appointed for the purpose
ning the support of the International Association of
es. An international committee, consisting of one dele-
ı each of the participating societies, was appointed and
ed to invite at its discretion other societies and indi-
o co-operate. A discussion took place on the formation
visional programme of observations, and at the conclu-
ommittee, consisting of Professors Hale, Schuster, and
ıs, was nominated to draw up such a programme.

heliographs and spectrographs for the study of sun-spots and other solar phenomena.

The present staff of the Observatory consists of the Director (Professor Hale), with Mr. Ellerman and Mr. Adams, who are associated with him in solar and spectroscopic researches; Mr. Ritchey, who is in charge of the workshop and optical experiments; and Professor Barnard, who has taken to Mount Wilson the large doublet lens presented to him by Miss Bruce. The optical work conducted under Mr. Ritchey's supervision includes the fusing of quartz with a view to the possibility of making mirrors from it. It is hoped that the five-foot telescope constructed by Mr. Ritchey will be mounted on the summit; but this will involve in the first instance the widening of the trail up the mountain, which is at present too narrow to allow of the transport of the parts of the instrument. The conditions of residence at the new Observatory will be somewhat novel: the wives and families of the observers will reside in Pasadena, the observers themselves occupying "monastic" quarters on the summit while at work, and descending for brief week-end visits.

Note added later.—The Observatory has now been definitely placed under the Carnegie Institution, and is named the "Solar Observatory," Mount Wilson, California. All letters should be addressed to "Observatory Office," Pasadena, California.

The Astrographic Chart and Catalogue.

A footnote in last year's report (see *Monthly Notices*, vol. lxiv. p. 374) stated that four fascicules of the Astrographic Catalogue had been received from the Algiers Observatory. These, with four fascicules from the Toulouse Observatory and a volume containing the measured rectilinear co-ordinates of the stars on half the plates of the Greenwich zone, *i.e.* the plates which cover the zone of declination from 64° N. to 72° N., form the total of the results of the work published last year.

The publications of the French observatories are similar in form and in most of their details to the volume previously published by the Paris Observatory. Essential points in which the English catalogue differs from the French arise from the fact that at Greenwich two plates, or rather portions of two plates, which cover the same area of the sky are measured together in the "duplex" micrometer, and hence each plate is measured only as far as the lines in which it intersects the adjacent plates whose centres have the same declination, or differ from it by two degrees, north and south, whereas all the stars on each of the plates taken at the French observatories are measured. As a result of this the Greenwich catalogue contains two measured positions and only two of every star; but in the system in which each plate is measured separately and

the same star can occur four or even five times, and it in the printed catalogue each time with a different ion, for in this system the stars are numbered consecu- beginning with unity, on each plate. In the English ach star is known by the number of the zone of declina- which it occurs and its number in that zone. With the micrometer measurement is made by means of a scale in piece, divided into tenths and hundredths of a *réseau* (300″), and the co-ordinates in the Greenwich Catalogue n in terms of a *réseau* interval to the fourth decimal. nch plates are measured by means of a micrometer screw, co-ordinates are given in millimètres also to the fourth of the unit. In all cases the measured co-ordinates are corrected for scale value or for orientation of the plate. lgiers Catalogue, as in the Greenwich, no correction for errors of the *réseau* have been applied, but tables of such hen they are sensible, and of plate constants are given er information in all the catalogues sufficient to convert ple measures into Right Ascension and Declination. The volumes give the constants together with the places of the quatorial co-ordinates from which they are deduced on the

minutes' exposure) have been made at the Royal Observatory, Greenwich, by a photographic process already described (*Monthly Notices*, vol. lxiii. p. 132), and copies of 136 fields in the zones 65°, 66°, 67° have been distributed during 1904 to fifty observatories and other institutions. Similar copies, but made by heliogravure process, continue to be distributed by the French observatories, and the numbers at present received are, Paris 207, Algiers 176, Toulouse 107. H. P. H.

Universal Time, Longitudes, and Geodesy.

From 1904 October 30 the time-ball at Hong Kong has been dropped by order of the Governor of the Colony at $17^h\ 0^m\ 0^s$ G.M.T., which is $23^m\ 18^s{\cdot}14$ in advance of $1^h\ 0^m\ 0^s$ of Hong Kong mean time. This announcement, which at first sight seems unimportant, is actually the final step in a movement which has resulted in the adoption as standard of the time of the zone eight hours east of Greenwich in Eastern China and in the British Colonies, Hong Kong, Labuan, and British North Borneo, which come within its limits. It is probable that the time of the seventh hourly meridian will be adopted in Western China, but the exact line of delimitation is not yet settled.

A new time system has been proposed for India, Further India, and Burmah. The scheme suggested is that the times of the meridians $5\frac{1}{2}$ and $6\frac{1}{2}$ hours east of Greenwich should be adopted in these territories. No reason is given why hourly meridians five hours and six hours east should not be chosen; a plan which would bring the time of India into harmony with that of almost the whole of the civilised world.

During the year the definitive result of the longitude Potsdam-Greenwich determined by Professor Albrecht and Dr. Wanach, of the Prussian Geodetic Institute, has been published. The difference of longitude between the meridian of the transit room at the Geodetic Institute at Potsdam and the transit circle at Greenwich was found to be $52^m\ 16^s{\cdot}051$, and the probable error of the determination $\pm 0^s{\cdot}003$. It will be remembered that in this work star transits were recorded by means of Repsold registering micrometers, and it is worthy of note that the difference of personal equation of the observers derived from the observations is $0^s{\cdot}000 \pm 0^s{\cdot}005$.

By help of the result of a determination of the arc Berlin-Paris made in 1877 by officers of the Institute, Professor Albrecht deduces a value of the arc Paris-Greenwich $9^m\ 20^s{\cdot}912$, or by using a value of the arc Berlin-Paris taken from *Bakhuyzen's Compensation* the difference between Paris and Greenwich arrived at is $9^m\ 20^s{\cdot}887$.

The results of the direct determinations of the arc Paris-Greenwich made in 1902 have also been published. The value

y the French observers is $9^m\ 20^s{\cdot}974$, with a pr
$\pm 0^s{\cdot}008$. The English result is $9^m\ 20^s{\cdot}932 \pm 0^s{\cdot}00$
tion may be made here of the result of the work
wedish expedition to Spitzbergen to measure the
of the meridian in a northern latitude, a summ
vas published in the *Bulletin Astronomique* for
One principal fact determined appears to be th
between the parallels of latitude of Keilhau and T

$$272072^{m}{\cdot}3 \pm 4^{m}{\cdot}6$$

		°	′	″ ″
Latitude of Keilhau ...	...	76	37	44·6 ± 0·2
Latitude of Thumb Point	...	79	3	59·1 ± 0·3

calculations the ellipsoid of Bessel has been tal

H. P

e this has been in type, Professor Albrecht has combined the
legraphic European longitude determinations among whic
in this note are included to form a "Compensation." Th
for the arc Potsdam-Greenwich resulting from this is 52^m

List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary.

His Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The French Government.
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British Association for the Advancement of Science
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British Horological Institute.
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Cambridge Philosophical Society.
Cardiff, Astronomical Society of Wales.
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Dublin, Royal Society.
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Liverpool Observatory.
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delaide Government Observatory.
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llegheny Observatory.
merica, Astronomical and Astrophysical Society.
msterdam, Royal Academy of Sciences.
asel University.
atavia, Royal Magnetical and Meteorological Observatory.
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erlin, German Physical Society.
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erne University.
ombay Branch of the Royal Asiatic Society.
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Kodaikánal Observatory.
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Leipzig, Astronomical Society.
Leipzig, Prince Jablonowski Society.
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Lick Observatory.
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Lyons Observatory.
Madrid, Astronomical Observatory.
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Manila Observatory.
Manila, Philippine Weather Bureau.
Mauritius, Royal Alfred Observatory.
Milan, Royal Observatory.
Missouri, Laws Observatory.
Moncalieri Observatory.
Montpellier, Academy of Sciences.
Moscow, Imperial Society of Naturalists.
Munich, Royal Bavarian Academy of Sciences.
Munich, Royal Observatory.
Naples, Royal Academy of Sciences.
Natal Observatory.
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Paris, Astronomical Society of France.
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Paris, École Polytechnique.
Paris, International Astrophotographic Congress.
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Paris Observatory.
Paris, Philomathic Society.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Pola, Imperial Hydrographic Office.
Potsdam, Central International Geodetic Bureau.
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Pulkowa Observatory.

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St. Petersburg, Imperial Academy of Sciences.
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Vienna, Imperial Military Geographical Institute.
Vienna, Imperial University Observatory.
Vienna, Von Kuffner Observatory.
Washington, Navy Department.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Naval Observatory.
Yale University Astronomical Observatory.
Yerkes Observatory.
Zürich, Central Meteorological Institute of Switzerland.
Zürich, Natural History Society.
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Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of the "Astronomische Nachrichten."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
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ADDRESS

l by the President, Professor H. H. Turner, on presenting Gold Medal of the Society to Professor Lewis Boss.

Gold Medal of the Society has been awarded to Professor oss "for his long-continued work on the positions and otions of fundamental stars," and it is now my pleasant ay before you the grounds on which the Council have s award.

we hope, our medals have been bestowed in recognition st work of the time, our list of medallists should be an

proper motions, but the general apparent motion which we call precession, and ultimately the systematic drift due to the motion of the solar system through space. Thus in 1850 Otto von Struve received the medal for his paper on the constant of precession; in 1852 we find the name of C. A. F. Peters, with a reference to his determination of nutation; and in 1858, in awarding the medal to the Rev. R. Main, the President of the day specially referred to the proper motion of the solar system, which, Mr. Main conceived, "ought to be admitted among the established facts of astronomy."

As one catalogue after another was compared for purposes of this kind with Bradley's observations it became more and more important to make sure that these observations, which were adopted by universal consent as the starting-point of all such inquiries, were reduced in the best possible way; and accordingly we find from our list that in 1888, so recently as to be within the memory of many here present, our medal was awarded to Professor Arthur Auwers "for his re-reduction of Bradley's observations."

The present award reminds us that the second period has in its turn been succeeded by a third, which discards Bradley's observations as the starting-point. The name and fame of Bradley are dear to us not merely because he was an Englishman, and represented England as Astronomer-Royal, but because of the greatness of the man himself. But however loth we may be to leave the old tradition which is rooted in Bradley we must recognise that we are come to the parting of the ways. Our medallist of to day struck out the new path in his first great work a quarter of a century ago, and has trodden it steadily ever since. Dr. Auwers, who paid the tribute to Bradley of re-reducing his observations in order that they might yield their utmost, and who has plodded steadily and loyally along the old highway to the very last, has recently* retraced his steps to the turning, and taken the new road along which we all must travel for the future.

I should pay a poor compliment to our medallist if I allowed a possibility of existence to the misconception that the modern views involve any disparagement of Bradley himself. He would, I am sure, defer to no one in his admiration for Bradley's greatness, and for the splendid results which he obtained from the instruments of that day. It is the instruments alone that are in question, or rather about which there is no question. They were certainly inferior to those available in 1820, and it appears that the inferiority was so great that it is now preferable to use the observations of 1820 as a starting-point, in spite of

* In his most recent rectification of the Fundamental Catalogue of the Berlin *Jahrbuch*, under date 1903 November 1, Dr. Auwers bases the declinations on fifty series *with epochs from* 1821 (*Bessel*) *to* 1897 (*Munich and Ottakring*). See *Ast. Nach.* No. 3927, p. 231, paragraph 3.

's great skill as an observer and his greater antiquity.*
situations have arisen in other departments of astronomy.
tance, until recently it was considered that the mean
of the Moon and its changes could be best evaluated by
from the naked-eye observations of ancient eclipses and
ng these with modern observations. The time elapsed
e invention of the telescope has made more accurate
ions possible is too short—so it was considered—to give
mation which would compare in value with that furnished
uch longer interval. But recently we have found reason
the soundness of this view. The ancient observations
cted by uncertainties of historic record, and it seems
ssible that modern observations can be used rather to
he old records and identifications than that these can
thing to what can be obtained from comparatively recent
And so in the case of Bradley's observations, which
the foundation of accurate work for so many years, it
ow seem that modern observations can rather tell us
re the division errors of Bradley's circle than that we
n any new facts by retaining the results obtained from
erfect circle as a starting-point.

as I have stated, was the view propounded with great

Astronomer to his chief apologising for the "unexpected delay" in transmission.

In the Introduction following this letter it is explained that the latitudes of twenty-two stations in the vicinity of the 49th parallel, which separates the United States from Canada, depend on two factors—the accuracy of the observations made and the correctness of the declinations adopted : that the former might be considered beyond reproach, and that it therefore became necessary to examine the latter. To make the declinations as trustworthy as possible all the authorities which could be obtained from the library of the United States Naval Observatory had been consulted ; that a comparison of these various catalogues *inter se* was naturally suggested ; that the scope of the work gradually enlarged, until the final outcome was the volume in question, containing an exhaustive discussion of nearly one hundred fundamental catalogues, tables for the systematic correction of them all, and a final catalogue of the declinations and proper motions of 500 stars for the epoch 1875, which at once took a place in the very front rank. To emphasise the special characteristic of this work to which I have already called attention I will quote the following paragraph from the "preliminary statement :"—

> It will be shown that the interval of time between the group of early determinations by Bessel (1821), Struve (1824), and Argelander (1829), and the later ones at Leiden, Melbourne, Greenwich, and Washington Observatories (not to mention intermediate catalogues), is quite sufficient for an independent judgment as to the approximate accuracy and consequent weight of Bradley's results, and that a reliable system of corrections to the various catalogues may be founded on a discussion of recent catalogues alone, taking as the earliest that of Bessel for the mean epoch 1821 (p. [7] or 413).

We have been led to believe that our cousins in the United States regard their boundaries somewhat seriously. There is a well-known story, scarcely, however, suitable for repetition from this Chair, which assigns as one boundary the North Pole, and as another the Day of Judgment. But I venture to think that even these ideals, after making due allowance for the national love for picturesqueness of statement, scarcely surpass in magnificence the conception of duty which led a young assistant astronomer, in the ordinary course of his work on a Boundary Commission, to undertake, as Appendix H to the Report, the collation and revision of all existing catalogues, and to initiate a totally new departure in principle which the world has now adopted some quarter of a century later.

In an Address like the present it is impossible to follow this work in detail ; but the brief description already given is doubtless sufficient to convey an idea of the colossal labour involved and of the energy of the man who could carry it through. Before passing on to his other work, however, I will add, by way of emphasis, his own description of his attitude at the

on of his exertions. He proceeded by the method of
ve approximations, which involved going over the whole
at least twice; and so little was his ardour damped by
etition that he says at the end of it :—

ld have been for me a pleasant task to have undertaken, with the
ne places now available, a third approximation to the systematic
s and weights. But the real object of the work has been already
y accomplished, and the time is not at my disposal for the purpose
or 570).

in fact been appointed, during the course of the work,
of the Dudley Observatory at Albany, a position which
holds, and which he has made famous. We can readily
nd how, in the early years of such an appointment, his
n was claimed by matters more directly relating to the
tory, and especially by the Albany zone observations
′ to +5° 10′), which were undertaken according to the
the *Astronomische Gesellschaft.* This work was com-
in 1878 August, immediately after the return of the
from observation of the total solar eclipse of that
d claimed his attention for nearly a dozen years in all.
ing that during this time Professor Boss took charge of

those two magnitudes fainter. He found that the Sun's apparent angular velocity came out nearly the same for both series, and was thus led to the startling conclusion that for the stars considered "the true criterion for estimating their average distances is very nearly independent of the magnitude, and that it is almost wholly some function of the apparent proper motion." This fundamental fact, obtained from the discussion of observations necessarily restricted to a narrow belt of the heavens, was soon afterwards [*] confirmed by Dr. Oscar Stumpe, using independent material applicable to the whole sky.

On the completion of the Albany zone, or perhaps even before it was finished, Professor Boss began to do what he could for the Southern Hemisphere by observing stars in the region —20° to —40°. It is among astronomers a well-known and deeply regretted fact that owing to the accumulation of observatories almost exclusively in the Northern Hemisphere our knowledge of the southern sky is far behind that of the northern. Professor Boss was director of one of the numerous northern observatories, but he reached out southwards as far as possible, and did what he could to lessen the disparity. Moreover, though restricted as regards observation he was free as regards discussion; and he brought the same skill to bear on the collation of southern catalogues that he had formerly displayed for northern. In 1898 he published a systematic comparison of seventeen southern catalogues and a standard system of places and proper motions of 179 southern stars (*A. J.* Nos. 448–450). Three years later he was able to include a few more catalogues, and to deduce from southern stars a determination of the solar motion in space, which afforded satisfactory independent confirmation of the results found from northern stars, and brought out several minor features of interest (*A. J.* 499–501).

Meanwhile the Dudley Observatory had been, in 1893, transferred to a new site. The old Observatory was near a great railroad which skirted the hill at a distance of about 160 yards, and was in need of extensive repair. Miss C. W. Bruce, of New York, who has been a liberal benefactor to astronomy in so many directions, offered $25,000 additional endowment for the institution on condition that the "friends and neighbours" of the Observatory should secure its removal to a new and better site. This condition was promptly met by the subscription of another $25,000 by sixty-five individuals, nearly all of whom were residents of Albany; and the city itself gave land for the new site and $15,000 in exchange for the grounds and buildings of the old Observatory. Miss Bruce thereupon increased her donations to $35,000. Professor Boss thus found himself in a greatly improved position. He was able to superintend personally

[*] The conclusions of Professor Boss were published in the *Astronomical Journal* for 1890 March 14. Dr. Stumpe's research is dated 1890 June and is published in *Astronomische Nachrichten*, Nos. 2999–3000, under date 1890 October 21: it contains no reference to Professor Boss's paper.

G G

ction of his transit circle at the new Observatory, and
cial pains with the foundations. The observations of
stars, temporarily interrupted, were soon resumed;
Pruyn Equatorial of 12 inches aperture was added to the
ory equipment by the liberality of the sons of the late
I. Pruyn, formerly president of the Observatory Trustees.
an important question arose in consequence of the
Could the meridian circle be regarded as essentially
instrument as before? or had the inevitable small jars
produced alterations, too slight perhaps to be noticed
e, but serious for astronomical observations? One test
applied which might afford at any rate a partial answer
questions. We have seen that the division errors and
of the two circles were carefully determined at the old
y might be re-determined after the re-erection for com-
with the former values. It is true that the labour in-
as enormous, and might well have deterred a less resolute
our medallist. To him it was a mere circumstance,
ntered upon the "fourteen months' convict labour for
sons"—as I have heard him describe it—without a
of evading any portion of it. Rather did he improve the
by pushing the research further than he had done

vice versa. But gradually he was led to a general scheme of consolidation for all catalogues, both north and south, which is still engaging his attention, though he has already completed the first and most important stage, and published the results in a series of memoirs of which I shall presently speak.

But before doing so I would call your attention to the steadiness of purpose which runs through all the work of our medallist. The terms of the Council award, "his *long-continued* work on the positions and proper motions of fundamental stars," are particularly appropriate, for the work has been continued throughout his career as an astronomer. His appointment to the Dudley Observatory hastened the close of his discussion of the northern declinations, but only initiated his attack on the main problem from a new point of view. The restriction to zone observations, which might have swept the notion of fundamental discussion out of the thoughts of another, did not deter Professor Boss from deducing the constant of precession and the elements of solar motion in space from these same zone observations.

But it must not be supposed that he neglected all other work. The pages of the *Astronomical Journal* contain numerous papers by him relating to comets, both observations and ephemerides. I will venture to quote from one of these papers a few words which seem to me to indicate the characteristically wide sweep of his outlook :—

> It had occurred to me [he says] that the theory of the September comet of 1882 possesses uncommon interest from more than one point of view, and that this interest may become very intense and extremely inquisitive during the twenty-seventh century, when the fragments of the comet shall successively make their next appearance at perihelion, and when the positions of comparison stars may be investigated with a degree of rigour unattainable at the present time (*A. J.* No. 226, p. 75).

Accordingly, he gives the positions of 465 comparison stars determined at Albany; and I will hazard the prophecy that when the astronomers of the twenty-seventh century come to investigate them they will give them the maximum weight for the epoch.

But he rightly judged that he could be of best service to astronomy by using the fruits of his ripe experience in the line of work he had adopted from the first, and that such work as could be done equally well by others should be left to others; and this position he has consistently maintained in reply to inquiries from those who found it difficult to understand the importance of fundamental discussions, and who looked rather for tangible discoveries. Thus it is related of him that when a member of his Board of Trustees confessed to some disappointment that no comets were discovered at the Dudley Observatory he explained what a drawback it would be to neglect his cherished work for such a purpose, but declared that he could

ertainly discover a comet vicariously for them if they
pply a modest sum, which he named, for payment of an
. And this promise he was actually able to perform!
ey was promptly subscribed; the assistant was engaged
ucted what to do and how to do it, and within a short
notable Comet 1882 (*a*) was found. It was a bold
ut Professor Boss was playing for a big stake. He
o obtain freedom to work in the way he believed to be
portant for astronomy, while retaining the confidence and
of his trustees; and by taking a risk which he felt was
asonable he managed to secure this happy combination.
w at any rate that he has produced no lack of work
own heart; and that he has the cordial support of the
trustees and the citizens of Albany generally we know
ready way in which they subscribed the money requisite
emoval and renovation of the Observatory in 1893.

we must now turn to the work which is occupying the
n of our medallist at the present time, and of which an
nt section has been recently published in a series of
originally printed in the *Astronomical Journal* and
rds collected under the title "A Catalogue of 627

I shall content myself with special references to two points of general interest which will illustrate the character of Professor Boss's methods and the fundamental nature of the results obtained.

The first is taken from his discussion of magnitude equation. For the benefit of those whose work lies in directions other than fundamental astronomy I may briefly recall the fact that this refinement of what has long been known as personal equation was definitely * discovered by Sir David Gill in his discussion of the comparison stars for *Mars* in 1878, and has since that time occupied an ever-increasing share of the attention of astronomers. He found that when the observations made by two different observers were compared they differed by an amount which varied with the brightness or magnitude of the star compared. Hence the name "magnitude equation." As in the case of the older "personal" equation, this kind of error was first noticed in connexion with transit observations; but it has been sought and found in other directions, even in photographic measures, though the origin of the discrepancy is there essentially different in character. It seems probable that magnitude-equation has taken up a permanent position as a factor—and a very troublesome factor—in all astronomical measurement of great refinement.

But we are concerned immediately with the particular form of it which occurs in making transit observations, and which consists in the fact that the observer, watching the passage of a faint star over a wire, tends to record a later instant than he would for a bright star. I have used the definite word "later" advisedly, for it has been ascertained that, while the amount of lag for one observer is different from that for another, there is a general consensus to be late for faint stars, or, if we prefer the statement, early for bright ones.

It has been ascertained by Professor Boss that the peculiarity for a given individual persists in spite of very deliberate changes in method of observing. It is well known to transit observers that they may adopt one or other of two mental processes in pressing the electric key to record a transit: they may commence pressing slightly before the star reaches the wire, so that the contact may occur as nearly as possible when the star is centrally on the wire, *or* they may wait until the star is on the wire and then begin to press. The difference may seem trivial to those who have not tried it in practice, but it represents a very real change in method to the observer. Professor Boss devoted some months to changing his personal habit from one plan to the other, and succeeded to his complete satisfaction, but found that nevertheless his magnitude-equation remained unchanged (*A. J.* No. 516, p. 100).

But a much greater revolution than this has been made in the

* Argelander and Gould had suggested the probability of its existence, but these were mere conjectures.

on of transits during the last century. Before these
lectric apparatus, when we merely press a button, there
old days of eye-and-ear observing—a completely dif-
thod. Was there a magnitude-equation then? and was
same kind as in these days? If not, then the proper
of stars deduced from a comparison of ancient and
bservations will be systematically different according as
are bright or faint; and this might lead to erroneous
ns, for instance, about the distance of the faint stars as
with bright; in other words, about the structure of the
for in such ways does our knowledge of the vast in
y depend upon our care of the minute. We must find
e can, what was the average character of magnitude-
in eye-and-ear transits compared with its average
value; and Professor Boss's conclusion, from an ex-
discussion of all these catalogues, that for all practical
this troublesome source of error has remained un-
* by the revolution in method is not only of the first
ce, but particularly welcome.

second illustration I take, not one of the results obtained
but one of his methods of work—viz. his method of
g a northern and a southern catalogue so as to obtain a

Cape observations; it only brings out the strength of the combination. Near the Greenwich zenith the Greenwich refractions would be sensibly the same, whatever reasonable value we assigned to the Greenwich constant, and the comparisons therefore leave us free for the evaluation of the Cape constant. Near the Cape zenith, similarly, the Cape refractions do not matter, and we are left free to determine those of Greenwich. The mutual accommodation is so complete that we are almost reminded of the classical instance of the united couple, one of whom could eat no lean, the other no fat. But there is one small flaw in the agreement. Refraction is not the only source of error in declination observations; there are instrumental errors as well; and these are necessarily entangled with the uncertainties of refraction. By heroic labour these instrumental errors may be ascertained; but there are not many men who, like our medallist, will cheerfully embark on "fourteen months' convict labour" to investigate them. A less satisfactory alternative is to trust to the general elimination of these individual errors in the mean of a number of catalogues made with different instruments; but we are here met by the difficulty that in the Southern Hemisphere the number of instruments is lamentably few, and in past years was fewer still; so that the total number of southern catalogues available for combination with northern on this beautiful plan is very small. Hence we are now in a position to gauge the merits of a scheme which I know lies very near the heart of our medallist, and which it is only necessary to mention in order to recognise its great importance for fundamental astronomy. We have seen that Professor Boss has determined the instrumental errors of his Olcott meridian-circle with the utmost care on two occasions, obtaining results which mutually confirm each other. Moreover, the instrument was transported bodily to some distance between the determinations without apparent disturbance, so that the possibility of moving it without injury has been demonstrated. Why, then, should it not be transported bodily to the Southern Hemisphere, and a southern catalogue made with it for comparison with observations already made in the Northern Hemisphere, which may possibly be supplemented by others on its return? In this way the uncertain factor in the combination of the two catalogues would be eliminated; the instrumental errors would be the same in both cases, and would, moreover, be accurately known. The observations would be entirely free for the determination of the two refraction constants, and a system of star-places would result of an excellence hitherto unparalleled.

This, as I have said, is the scheme which has gradually matured in Professor Boss's mind during a life of concentrated work steadily directed towards one goal, though as yet he cannot foresee with satisfactory probability the provision of means for putting it into execution.

It may well excite our wondering admiration to find that our medallist, after the long and arduous labours I have so inade-

described to you, with work, too, in hand requiring ing attention at the present time, should be looking ot to a period of well-earned leisure, but to a scheme of l which involves, not only considerable risk and anxiety, renewed assiduity such as a younger man might well om, but exile from home for a number of years. There ut one opinion as to the value of such an enterprise, and thought in the minds of all those anxious for the welfare omy—an earnest hope that means and opportunity may l for putting so noble a project into execution. We may e that we are thereby hoping that the work of our t, as it has been "long continued" in the past, shall be continued in the future; but at the same time we are hat for such a man the hope is only another expression e for his long-continued happiness.

he beginning of this Address I referred to our list of ts as in some sort an epitome of astronomical history he past eighty-five years. One of the features of that which gives us as Englishmen peculiar gratification, and faithfully reflected in this list, is the steady and rapid nent of astronomical work of the first order in the States. At the foundation of our Society it could

work to undertake it. In their absence it has been a great pleasure to us to be honoured by the genial presence of Mr. Choate; and it is particularly kind of him to-day to spare us a few moments from the busy weeks preceding a departure which the whole of England unites in deploring.

(The President then, addressing the American Ambassador, said:)

Mr. Choate, in sending this medal to Professor Lewis Boss will your Excellency kindly assure him of our great admiration for his long-continued work and our deep sense of its fundamental importance for astronomy, and our earnest hope that means may be found for carrying into effect his splendid plans for the future?

The Jackson-Gwilt Gift and Medal.

The Jackson-Gwilt Gift and Medal have been awarded to Mr. John Tebbutt, of Windsor, N.S.W., for his important observations of comets and double stars and his long-continued services to astronomy in Australia, extending over forty years.

This gift has only twice been awarded previously—in 1902 to Dr. Anderson, and in 1897 to Mr. Lewis Swift. In announcing the award in 1897 the President of the day stated that, after some consideration, he had decided not to give an address in connexion with the award, and I shall follow the precedent thus set. But there can be no reason why I should not recall to your memory that Mr. Tebbutt began astronomical work in 1854, and is only now relinquishing it at the age of seventy; that amid surroundings which gave him little encouragement he has made regular and systematic observations during half a century, including, for instance, those of some 1400 occultations of stars by the Moon and valuable measures of double stars; that he has contributed over eighty papers to the *Monthly Notices*; and has, moreover, discovered several comets, including the notable ones of 1861 and of 1881, the orbits of which he computed from his own observations.

In handing this medal to the Secretary for transmission, with the gift, to Mr. Tebbutt, I will ask him to convey our hearty congratulations to the recipient on the accomplishment of half a century of single-handed astronomical work for which it would be difficult, if not impossible, to find a parallel, and our delight that Mr. Tebbutt should be entering upon the rare enjoyment of a thoroughly well-earned period of rest.

ıeeting then proceeded to the election of Officers and
ɔr the ensuing year, when the following Fellows were

President.

MAW, Esq.

Vice-Presidents.

/. H. M. CHRISTIE, K.C.B., M.A., D.Sc., F.R.S.,
tronomer-Royal.
P. A. MACMAHON, D.Sc., F.R.S.
NEWALL, Esq., M.A., F.R S.
TURNER, Esq., D.Sc., F.R.S., Savilian Professor of
tronomy, Oxford.

Treasurer.

E. H. HILLS, C.M.G., R.E.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXV. MARCH 10, 1905. No. 5

W. H. MAW, Esq., PRESIDENT, in the Chair.

Brandon T. Brierley, F.G.S., Assoc.M.Inst.C.E., Linthwaite, Delph, near Oldham, Yorkshire;
Maurice Farman, Observatoire de Chevreuse, à Jagny, par Dampierre, Seine-et-Oise, France;
Willie Venner Merrifield, B.A., Liverpool Corporation Nautical College, Liverpool; and 5 Green Bank, Waterloo, near Liverpool;
Isaac Molloy, M.A., Lützen, Glenageary, Kingstown, Dublin;
Alfred Edward Nicholls, King Edward VII. Nautical School, London, E.; and Cotswold, Hornchurch, Essex; and
John Wearing, Garsdale, Sedbergh, Yorkshire,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:

Scriven Bolton, 24 Kensington Terrace, Hyde Park, Leeds (proposed by Richard Kerr);
Bahne Bonniksen, 16 Norfolk Street, Coventry (proposed by Richard Inwards);
Edward Turner Cottingham, Scientific Instrument Maker, The Limes, Thrapston (proposed by Julien Tripplin);
William George Hooper, Wiverton House, Musters Road, West Bridgford, Nottingham (proposed by Richard Kerr);

Marshall, Librarian, Filey House, Livingstone Road, carborough, Yorkshire (proposed by the Rev. T. E. R. hillips) ; and

Pearson, M.A., LL.B., F.R.S., Professor of Applied lathematics and Mechanics, University College, London ; Well Road, Hampstead, N.W. (proposed by H. H. urner).

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ty presents were announced as having been received since ordinary meeting, including, among others :

volumes of M.S. Meridian observations made at the Observatory, 1840–51, presented by the India Office ; arts of the Astrographic Chart of the Heavens, presented Royal Observatory, Greenwich ; stereoscopic views of the esented by T. E. Heath.

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nination of the Constant of Precession and the Direction

a. Stars whose R.A. lie between 6^h–18^h give a smaller value of A than those which lie between 18^h–6^h.

b. Stars of Types I. and II. differ considerably in the positions they assign to the position of the apex of the Sun's motion.

c. The declination of the apex progresses from south to north as the stars' magnitude diminishes, and the right ascension is small for very bright stars, and large for faint stars.

d. Stars whose centennial proper motions are less than 10″ place D north of the position derived from stars whose centennial proper motions are greater than 10″.

4. The most probable value of the position of the apex of the Sun's motion derived from the discussion is

$$A = 275^\circ \text{ or } 18^h\ 20^m$$
$$D = 37$$

Position of the Sun's Apex from Different Groups of Stars (see p. pp. 445–8).

M.	A.	D.	No. of Stars.	General Remarks.
				General solution.—P.M. 0″–20″.—Zone 5°–52°.
″ 2·40	° 275	° 38	4001	Equal weights to each star.
2·55	272	31		„ „ equal areas.
				Solutions according to Type of Spectrum.
2·44	269	23	1100	Type I. — Equal weight to each star.
2·79	273	37	866	„ II. — Equal weight to each star.
2·42	280	41	2035	Remainder — Equal weight to each star.
				Solutions according to size of P.M.—Zone 5°–52°.
				P.M.
1·17	273	39	2885	″ ″ 0–5 Equal weights to each star.
1·08	278	34		0–5 „ „ equal areas.
4·47	269	37½	800	5–10 „ „ each star.
8·36	273½	22	316	10–20 „ „ „
25·11	275½	30½	163	>20 „ „ „
23·5	272½	34	89	Type II. > 20 „ „ „
				Solutions in order of star magnitude.—Zone 15°–52°.
				Mag. m m
3·96	245	16	200	1·0–4·9 — Equal weights to equal areas.
3·18	268	27	454	5·0–5·9 — Equal weights to equal areas.
2·85	278	33	1003	6·0–6·9 — Equal weights to equal areas.
2·24	280	38½	1239	7·0–7·9 — Equal weights to equal areas.
2·32	272	43	811	8·0–8·9 — Equal weights to equal areas.

I. *Introductory.*

principal object of the Greenwich Second Ten-Year
e (1890) was the reobservation of the stars of Groom-
well known Circumpolar Catalogue, which had not been
at Greenwich as recently as the period of the Nine-Year
atalogue. Of the 4239 stars contained in Groombridge's
e 3645 occur in the Second Ten-Year (1890) Catalogue,
of the remainder in the Ten-Year (1880) Catalogue.
l number of Groombridge stars not occurring in these
s are found in the Nine-Year (1872) Catalogue, or have
erved since the conclusion of the 1890 Catalogue. There
been accumulated material for the determination of the
notions of a large number of stars with an average
between the observations of nearly eighty years.
nbridge's Catalogue has long been known to have some-
ge systematic errors, and from the remarks made by Sir
Airy in the introduction it seemed that there might be
ors of computation which an examination of the original
ons might discover. Accordingly the loan of the
idge manuscripts was requested by the Astronomer
om the Royal Astronomical Society, and a complete re-

In the declinations the difficulty of the determination of the division errors appears to have been satisfactorily overcome by comparison of the two positions of the instrument with Newcomb's Fundamental Catalogue, and by combining the results obtained for zenith distance north in one position with those of an equal distance south in the reversed position of the instrument. Thus corrections were found applicable from 39° to 52° N.P.D., and from 38° to 25°, or from 25° to 52° in all. The corrections from 10° to 25° N.P.D. were obtained from each position singly, and from 0° to 10° the material was so insufficient that no corrections have been applied. As the re-reduced catalogue is now in the press it is unnecessary to give further details of the reductions.

The Greenwich catalogues have been corrected to reduce them to Newcomb's Equinox in R.A., and to the Pulkowa refractions in N.P.D., in order that they may be strictly comparable with Groombridge's Catalogue. In the determination of the proper motions the Struve-Peters values of the constants m and n were used. The precessions were computed for 1810 and 1890, and the mean used in bringing the observations from 1810 to 1890, with a correction for third term where necessary. The deduced proper motions are therefore referred to the epoch 1850. In a small number of cases the observations of Groombridge were supplemented by those of the Radcliffe Catalogue, 1845, and very occasionally the position given by Groombridge was rejected, and the proper motions derived entirely from the Radcliffe and Greenwich Catalogues.

These observations of proper motion are in some ways very suitable for a determination of the constant of precession and of the solar motion. The stars are of mean magnitude $7^{m}\cdot0$, and therefore such as might well have been observed without any large errors depending on magnitude, and on the other hand they do not consist of too exclusively bright stars. The constant of precession and direction of the solar motion have been obtained from the proper motions of Auwers' Bradley by several distinguished astronomers, and therefore a determination made from the proper motions of the stars used by Groombridge is desirable, as it consists largely of fresh material, which, however, is confined to a very limited region of the sky. The proper motions in right ascension have from the outset been converted into arc.

II. *Distribution of the Stars according to* (i.) *Magnitude*, (ii.) *Size of Proper Motion, and* (iii.) *Type of Spectrum.*

(i.) *Distribution of Stars according to Magnitude.*

The stars observed in Groombridge's Catalogue lie within 52° of the North Pole, and are, generally speaking, the brighter stars in this part of the sky. It is only very occasionally that a star as faint as $9^{m}\cdot0$ is observed, and the mean magnitude is exactly $7^{m}\cdot0$. The magnitudes are taken from the *Harvard*

sterung where possible, and in other cases from the s of the *Astronomische Gesellschaft* or the *Bonn Durch-g.* The following table is an analysis of the stars' les in each octant of right ascension :—

Var.	$1^m.0$–$4^m.9$.	$5^m.0$–$5^m.9$.	$6^m.0$–$6^m.9$.	$7^m.0$–$7^m.9$.	$8^m.0$–$8^m.9$.	$9^m.0$–$9^m.5$.	Total.	Mean Mag. m
3	34	77	148	204	151	5	622	7.1
1	37	67	139	126	109	4	483	6.9
...	19	60	124	140	70	2	415	6.9
...	22	51	102	111	45	1	332	6.8
...	25	57	109	85	52	7	335	6.7
...	27	51	105	102	36	0	321	6.7
3	35	78	216	306	238	8	884	7.2
2	35	97	206	295	206	6	847	7.1
9	234	538	1149	1369	907	33	4239	7.0

ll be seen from the above table that only one-third of fall between 6^h and 18^h. This peculiarity in the distri- f the stars is in no way attributable to Groombridge's observing, but is entirely due to the actual differences of

Mag.	Total Number.	Numbers of Stars. Centennial Proper Motion.				Percentage of Stars. Centennial Proper Motion.			
m m		0″–5″.	5″–10″.	10″–20″.	>20″.	0″–5″.	5″–10″.	10″–20″.	>20″.
1 –3·9	71	20	15	23	13	28	21	32½	18½
4·0–4·9	163	86	34	23	21	53	21	14.	12
5·0–5·9	538	319	113	73	33	59	21	14	6
6·0–6·9	1149	764	239	95	51	66½	21	8	4½
7·0–7·9	1369	1008	248	78	36	74	18	5½	2½
8·0–	940	738	159	24	19	78½	17	2½	2
	4230	2935	808	316	173	69	19	8	4

An interesting feature in the above table is the consistency in the proportion of stars whose proper motion lies between 5″–10″ a century.

For the question of the solar motion it is most important to see how the proper motions are distributed in the sky. This is shown in the following tables, where the number of stars and percentages in these various groups are given for each octant :—

*Numbers of Stars whose Total Proper Motions lie between Certain Limits.**

Limits of R.A.	Total Number.	$6^m \cdot 5$ and Brighter. Centennial Proper Motion.				Total Number.	$6^m \cdot 6$ and Fainter. Centennial Proper Motion.			
h h		0″–5″.	5″–10″.	10″–20″.	>20″.		0″–5″.	5″–10″.	10″–20″.	>20″.
0– 3	188	109	44	21	14	427	334	67	19	7
3– 6	179	127	31	16	5	301	215	61	15	10
6– 9	147	80	38	21	8	267	185	58	21	3
9–12	124	50	37	26	11	205	115	52	24	14
12–15	149	66	31	35	17	181	120	40	14	7
15–18	129	66	32	15	16	192	130	38	15	9
18–21	234	146	43	26	19	641	513	96	18	14
21– 0	232	160	37	24	11	611	484	103	16	8
	1382	804	293	184	101	2825	2096	515	142	72

Percentage of Stars whose Total Proper Motions lie between Certain Limits.

Limits of R.A.	$6^m \cdot 5$ and Brighter. Centennial Proper Motion.				$6^m \cdot 6$ and Fainter. Centennial Proper Motion.			
h h	0″–5″.	5″–10″.	10″–20″.	>20″.	0″–5″.	5″–10″.	10″–20″.	>20″.
0– 3	59	22	11½	7½	78	16	14½	1½
3– 6	71	17½	8½	3	71½	20	5	3½
6– 9	55	25	14½	5½	69½	22	7½	1
9–12	41	30	20	9	56	25½	11½	7
12–15	44	20	24½	11½	66	22½	7½	4
15–18	51	25	11½	12½	67	20	8	5
18-21	63	18	11	8	80	15	3	2
21– 0	69	16	10½	4½	79½	16½	2½	1½
	58½	21	13	7½	74	18	5	3

* It will be noticed that these numbers do not exactly tally with those given above. A few stars have probably been omitted accidentally in the second table.

The most noticeable features in the above tables are :—

(i.) Stars with large proper motions seem to be more uniformly distributed than those with small proper motions, the latter showing a large increase about 0^h as compared with 12^h.

(ii.) Nearly 60 per cent. of the bright stars have a proper motion of less than 5″ a century, and more than 25 per cent. of the faint stars have a proper motion of more than 5″ a century.

(iii.) The tables of percentages show the large relative preponderance of stars of large proper motion—about 12^h of right ascension. Taking the proper motions as a gauge of the distances of the stars, there is here shown a want of symmetry in the distribution of the stars which may well affect the determination of the position of the solar apex.

(iii.) *Distribution of the Stars and their Proper Motions according to Type of Spectra.*

It has been shown by Kapteyn, from a discussion of the proper motions of the Bradley stars, that in general stars of Type II. have larger proper motions than those of Type I. It will be seen that this result is borne out by the following analysis of the stars common to the Groombridge and the Draper Catalogue (*Harvard Annals*, vol. xxvii.) under the headings of Type I. (classified by Professor Pickering as A, B, C, or D) and of Type II. (classified by the letters E to L). There are altogether 2096 Groombridge stars in the Draper Catalogue, distributed as follows :—

Distribution of Proper Motions of Stars of Type I.

Limits of R.A.	Mean Mag.	Total Number.	Numbers of Stars. Centennial Proper Motion.				Percentage of Stars. Centennial Proper Motions.			
h h	m		0″-5″.	5″-10″.	10″-20″.	>20″.	0″-5″.	5″-10″.	10″-20″.	>20″.
0- 3	6·6	211	154	43	11	3	73	20	5½	1½
3- 6	6·3	174	131	32	9	2	75	19	5	1
6- 9	6·4	105	76	24	4	1	72	23	4	1
9-12	6·2	72	41	21	6	4	56	30	8	6
12-15	5·7	85	46	15	20	4	53	18	24	5
15-18	6·0	92	64	20	6	2	70	22	6	2
18-21	6·2	162	134	19	6	3	80	12	4	2
21- 0	6·3	221	176	31	10	4	79	14	5	2
	6·3	1121	822	205	72	23	73	18	7	2

Distribution of Proper Motions of Stars of Type II.

Limits of R.A.	Mean Mag.	Total Number.	Numbers of Stars. Centennial Proper Motions.				Percentage of Stars. Centennial Proper Motions.			
h h	m		0″–″5.	5″–10″.	10″–20″.	>20″.	0″–5″.	5″–10″.	10″–20″.	>20′
0– 3	6·1	132	70	33	15	14	53	25	11	10
3– 6	6·0	106	68	16	15	7	64	15	14	7
6– 9	6·3	136	67	39	22	8	49	29	11	6
9–12	6·1	115	46	31	24	14	40	27	21	12
12–15	6·2	111	51	26	19	15	46	23	17	14
15–18	6·3	114	60	26	12	16	53	23	10	14
18–21	6·2	136	68	33	21	14	50	24	16	10
21–24	6·1	124	70	30	15	9	57	24	12	7
	6·2	974	500	234	133	97	51½	24	14½	10

Comparison of the above tables shows an entire difference in the distribution of the stars of Types I. and II. The stars of Type II. are distributed with extreme regularity in the different octants. On the other hand, the stars of Type I. have a very marked condensation between 18^h and 6^h where the Milky Way passes through the observed area. This is especially the case with the stars of smallest proper motion ($0''$–$5''$), and it can also be seen in the stars whose proper motions are between $5''$ and $10''$. The larger the proper motion of Type I. stars the more equal is the distribution in the octants.

Since the above tables were prepared vol. lvi. No. 1 of the *Annals of the Harvard College Observatory* has been received in which Professor Pickering gives an analysis of the distribution of the stars of different types in the whole of the Draper Catalogue, and concludes as follows: "The Universe is thus shown to consist of two portions, first, the stars of the first type, which though frequent in all parts of the sky predominate along a certain plane, thus forming the Milky Way. . . . The stars of the second and third types show no concentration in the Milky Way, but are, in general, uniformly distributed in all parts of the sky. These two portions should be treated separately in all discussion of the structure of the Universe, such as studies of proper motion, parallax, motion of the Sun in space, &c." The tables given above entirely confirm Professor Pickering's statements, and extend them in that they show that the uniformity of distribution of Type II. stars holds good when the stars are subdivided according to the magnitude of their proper motions.

The relatively large proper motions of stars of Type II. have been pointed out by Kapteyn from a discussion largely of Bradley proper motions; in brief the larger the proper motion the greater the chance that it is a star of Type II. This peculiarity is borne out by the following comparison of the present results with those given by Kapteyn. It should be noted that the lists are not entirely independent, as 627 of the 2095 Groombridge stars (*i.e.* 30 per cent.) are also Bradley stars.

Statistical Distribution of Proper Motions of Stars of Types I. and II.

Centennial Proper Motions.	Number of Stars. (Groombridge).		Numbers given by Kapteyn (Bradley).	
" "	Type I.	Type II.	Type I.	Type II.
0– 5	822	500	786	474
5–10	205	234	203	194
10–20	72	133	159	223
20–50	19	77	38	157
>50	4	20	3	58

The tables given above point very clearly to the special suitability of stars of Type II. for researches on the direction of the

Their distribution in space appears to be the same
from the Sun; the proper motions show their
rom the Sun, and distribution with respect to this
ame in all directions; and, further, their distances
the effect of parallactic motion is considerable.
ype I. are condensed near the Milky Way, and
the case with the stars of small proper motion.
hat the mean distances of these stars are different
ctions, and a difficulty is at once introduced into
on of the solar motion from them.

III. *The Precessional Constant* m.

on the mean proper motions are given for each three
scension, and the material is arranged for discus-
magnitude equation of Groombridge as compared
rn Greenwich observers, and the possibility of a
bright relatively to the faint stars, (*b*) a determi-
precessional constant *m*. The advantages of an
groups of three hours are that the data are com-
nall compass, and their general character more
ed than in more extended tables.

roper Motions of Stars of Different Magnitudes for
The proper motions in right ascension having been
into arc of a great circle the means were taken

Mean Centennial Proper Motions of Stars between the Limits 15° – 52° N.P.D. (omitting Stars whose Proper Motions are > 20″).

mits R.A.	Right Ascension.					North Polar Distance.				
	1^m–$4^m.9$.	$5^m.0$–$5^m.9$.	$6^m.0$–$6^m.9$.	$7^m.0$–$7^m.9$.	$8^m.0$–$8^m.9$.	1^m–$4^m.9$.	$5^m.0$–$5^m.9$.	$6^m.0$–$6^m.9$.	$7^m.0$–$7^m.9$.	$8^m.0$–$8^m.9$.
h	″	″	″	″	″	″	″	″	″	″
-3	+0·6	+0·5	+1·8	+1·5	+0·9	+1·9	+1·8	+1·5	+1·4	+1·1
-6	+0·2	+0·8	+1·1	+1·0	+0·7	+2·6	+3·3	+2·3	+2·1	+2·0
-9	−3·4	−1·8	−1·3	−1·0	−1·8	+4·1	+2·1	+2·9	+2·2	+2·2
-12	−4·6	−3·3	−2·7	−2·1	−3·1	+0·5	+1·8	+1·2	+0·7	+1·3
-15	−1·0	−4·3	−2·6	−1·7	−1·7	−1·5	−0·6	−0·2	−0·1	−0·1
18	+0·3	−0·6	−1·6	−1·5	−0·1	−2·1	−1·7	−0·7	0·0	+0·1
21	+2·2	+0·7	+0·5	+0·4	−0·1	−3·3	+0·5	+0·3	−0·1	+0·1
0	+3·2	+2·8	+1·5	+1·1	+0·8	+2·0	−0·4	+0·6	+0·7	+0·5
an	−0·31	−0·65	−0·41	−0·29	−0·55	+0·52	+0·85	+0·99	+0·86	+0·90

The solar motion is shown very clearly in each column of these tables, and will be fully considered in section V. Taking the results of the latter table as being more free from accidentally large proper motions, the means in R.A. are as follows :—

	m m	″
Mags.	1·0–4·9	−0·31
„	5·0–5·9	−0·65
„	6·0–6·9	−0·41
„	7·0–7·9	−0·29
„	8·0–8·9	−0·55

By taking the simple means the effect of solar motion is eliminated. The agreement of the results for all magnitudes shows that there is no rotation as a whole of the bright stars relatively to the faint stars in this part of the sky, and that Groombridge's magnitude equation was substantially the same as that of the modern Greenwich observers. The general mean of the R.A. results may arise from systematic errors, erroneous precession, or an accumulation of large proper motions about 12^h. Detailed consideration of these points follows. The mean results in N.P.D. are directly attributable to the solar motion.

(*b*) *The Precessional Constant* m.—The agreement of the mean proper motions in right ascension for stars of different magnitudes suggests that this method may be used for a determination of the precessional constant *m*. Omitting stars of centennial proper motion > 20″, and all stars within 15° of the pole, we

he following table of mean proper motions in z
for each three hours of right ascension :—

Proper Motion in Right Ascension for all Stars whose Cente
p.m. < 20″.

	15°–25°.	25°–35°.	35°–45°.
	″	″	″
	+2·32	+1·79	+0·94
	+1·82	+0·53	+0·97
	−0·82	−0·72	−1·99
	−1·65	−2·56	−1·86
	−1·78	−1·71	−2·36
	−0·34	−0·68	−1·16
	+1·21	+1·02	+0·65
	+2·24	+1·71	+1·30
...	+0·38	−0·05	−0·44

large value of the mean −1″·14 for the zone 4
some examination. The question arises whethe
ystematic error in the Groombridge Catalogue
or whether it may be attributed to those inequali
ibution of the stars and their proper motions to

siderable effect on the mean, and tables corresponding to the one on p. 438 have been formed in which more stars have been excluded. The two limits chosen are 10″ a century and 5″ a century. The former appears to be a sufficiently ample limit, but the latter is probably too small.

Mean Proper Motion in Right Ascension for all Stars whose Centennial p.m. < 10″.

	15°–25°.	25°–35°.	35°–45°.	45°–52°
	″	″	″	″
0– 3	+1·85	+1·78	+0·60	+0·40
3– 6	+1·55	+0·31	+0·50	+0·08
6– 9	−0·87	−0·64	−1·66	−1·49
9–12	−1·48	−1·63	−1·71	−2·51
12–15	−0·24	−1·86	−1·31	−2·14
15–18	−0·42	−0·65	−1·15	−0·70
18–21	+0·81	+0·51	+0·51	−0·12
21–24	+1·69	+1·31	+0·93	+0·55
Mean ...	+0·36	−0·11	−0·41	−0·73

Mean Proper Motions in Right Ascension for all Stars whose Centennial p.m. < 5″.

	15°–25°.	25°–35°.	35°–45°.	45°–52°.
	″	″	″	″
0– 3	+1·13	+1·32	+0·43	−0·01
3– 6	+1·27	+0·13	+0·38	+0·01
6– 9	−0·46	−0·63	−0·95	−0·85
9–12	−0·75	−0·66	−0·70	−1·32
12–15	−0·63	−1·36	−0·80	−1·10
15–18	−0·37	−0·67	−0·85	−0·33
18–21	+1·07	+0·37	+0·33	−0·11
21–24	+1·07	+0·77	+0·68	+0·01
Mean ...	+0·29	−0·09	−0·19	−0·46

Collecting the results we find for the mean proper motions in the four zones :

Limits of p.m.	15°–25°.	25°–35°.	35°–45°.	45°–52°.
″ ″	″	″	″	″
0–20	+0·38	−0·05	−0·44	−1·14
0–10	+0·36	−0·11	−0·41	−0·73
0– 5	+0·29	−0·09	−0·19	−0·46
Adopted values	+0·30	−0·10	−0·30	−0·60

These adopted values, when corrected for the systematic errors of the catalogue, form corrections $\Delta m \cos \delta_0$ to the adopted centennial value of the precessional constant m, δ_0 being the mean declination for each group.

ollowing table gives the corrections to Groombridge's to reduce it to the systems of Newcomb, Auwers, . The comparison with Newcomb has been made hat with Auwers is derived from his recently published he results of the new reduction having been sent to e Astronomer-Royal in advance), and that with Boss by the corrections Boss-Newcomb for 1810, derived from n. 531–2 to the corrections Newcomb-Groombridge.

Newc.-Groomb.	Auwers-Groomb.	Boss-Groomb.	Boss-News
s	s	s	s
+·18	+·21	+·09	−·09
+·14	+·14	+·13	−·01
+·06	+·06	+·06	·00
+·04	−·03	+·03	−·01
−·02	−·03	−·01	+·01
−·06	−·03	−·04	+·02
−·05	−·04	−·03	+·02
−·05	−·06	−·02	+·03
−·04	−·08	−·02	+·02

The solution of the above equations gives $\Delta m = +''\!\cdot\!18$ as the centennial correction to the Struve-Peters value of m, or $+''\!\cdot\!70$ to Newcomb's value. If the right ascensions of Groombridge had been reduced to Auwers's system by the corrections given by him, the deduced value of m would have been about $0''\!\cdot\!2$ per century larger, and reduced to Boss's system about $0''\!\cdot\!4$ smaller.

IV. *The Precessional Constant* n.

To determine the value of the precession, we should, if we could pick them out, use stars so distant that they are unaffected by the solar motion. Let X, Y, Z be the centennial displacement of the Sun relative to any class of stars, and let Δn be the correction required by the precessional constant n. Then m will require a correction, $\Delta n \cot \epsilon$, where ϵ is the obliquity of the ecliptic ; and each star will give rise to two equations :

$$\left.\begin{aligned} X \sin\alpha - Y \cos\alpha + \Delta n(\cot\epsilon \cos\delta + \sin\alpha \sin\delta) &= \mu \\ \text{and } X \cos\alpha \sin\delta + Y \sin\alpha \sin\delta - Z \cos\delta + \Delta n \cos\alpha &= -\mu' \end{aligned}\right\} \quad \begin{aligned} &\text{(i.)} \\ &\text{(ii.)} \end{aligned}$$

If the stars were so distant that the displacement of the Sun relative to them were zero, X, Y, and Z would vanish, and the above equations would give Δn. Apart from errors of observation μ and μ' would be entirely resolved into corrections to the adopted precession. If, on the other hand, we are dealing with a class of stars near the Sun, the displacements X, Y, Z will be large, and only a trifling part of the proper motions μ and μ' will be due to error of precession.

In this section the stars are divided into groups according to the magnitude of their proper motion, and the value of the precessional constant n is deduced from the consideration that stars of small and large proper motion should give the same value of the ratio X : Y.

The limitation of Groombridge's observations to within 52° of the pole would make the normal equations derivable directly from equation (ii.) unsatisfactory, and, though not quite to the same extent, the equations derivable from (i.). In both cases X and Δn would be difficult to separate.

Instead of treating Δn as an unknown quantity to be determined directly, equations have been formed giving the coordinates of the apex of the solar motions for stars with proper motion (1) between $0''$ and $5''$; (2) between $5''$ and $10''$; (3) between $10''$ and $20''$; and (4) $> 20''$ on two suppositions:

First, basing the proper motions on the centennial value of the Struve-Peters constants of precession, viz.

$$m = 4607''\!\cdot\!63 \qquad n = 2005''\!\cdot\!64$$

ond, basing the proper motions on the centennial value of
nb's constants of precession, viz.

$$m = 4607''\cdot 11 \qquad n = 2005''\cdot 11$$

tter object was affected by applying a correction to the
ial proper motions of $+0''\cdot 52 \cos \delta + 0''\cdot 53 \sin \delta \sin \alpha$ to the
censions and $+0''\cdot 53 \cos \alpha$ to the declinations. Roughly
g, this change in the precession adds $+0''\cdot 40$ to the value
erived from the right ascensions and $+0''\cdot 65$ to the value
from the declinations. The actual values found for
Y are as follows :—

Right Ascensions.				Declinations.			
Struve-Peters.		Newcomb.		Struve-Peters.		Newcomb.	
X	Y	X	Y	X	Y	X	Y
+2·87″	−21·83″	+3·25″	−21·85″	+·28″	−20·88″	+·92″	−20·89″
+·54	−7·62	+·95	−7·65	−·60	−8·54	+·11	−8·54
−·29	−3·68	+·09	−3·74	−·50	−3·46	+·14	−3·46
−·10	−1·02	+·25	−1·22	−·43	−·70	+·20	−·70
−·05	−0·92	+·38	−0·92	−·42	−·81	+·20	−·81

and small proper motions both for the right ascensions and declinations.

In the last section a correction of $+0''\cdot70$ was found to Newcomb's centennial value of m ($4607''\cdot11$). This implies a correction to n of $\frac{20}{46} \times 0''\cdot70$ or $+0''\cdot30$. The present reasoning requires a correction of about $\frac{1}{3} \times 0''\cdot53$ or $+0''\cdot17$. We have adopted the correction $+0''\cdot20$, giving for the centennial value of the precessional constants m and n for 1850.

$$\left.\begin{aligned} m &= 4607''\cdot57 \\ n &= 2005\cdot31 \end{aligned}\right\}$$

which amount to increasing Newcomb's value by $\frac{1}{10000}$th part.

The following values are derived from the discussion of the proper motions corrected for this new value of the precession and the systematic correction Δa_δ, as explained above

Centennial P.M.	From R.A.	From Dec.	Combined Result.
$< 20''$	278°	272°	$275\frac{1}{2}^\circ$
$10''$–$20''$	276	269	$273\frac{1}{2}$
5–10	$269\frac{1}{2}$	$268\frac{1}{2}$	269
0– 5	277	$265\frac{1}{2}$	273
0– 5	$283\frac{1}{2}$	$268\frac{1}{3}$	278

For comparison with the new value of n for 1850 the following values are taken from Newcomb's Precessional Constant, p. 10 :—

Bessel I.	$20''\cdot0413$	Newcomb (prelim. value)	$20''\cdot0479$
Bessel II.	$20\cdot0553$	Dreyer	$20\cdot0546$
Peters	$20\cdot0564$	Bolte	$20\cdot0537$
Leverrier	$20\cdot0524$	Newcomb	$20\cdot0511$
Oppolzer	$20\cdot0515$	Dyson & Thackeray	$20\cdot0531$
L. Struve	$20\cdot0452$		

V. *The Solar Motion.*

The difficulties which are inherent in the determination of the direction of the solar motion are illustrated to some extent in the statistics of Section II. We found there—

(i.) Want of uniformity in the distribution of the stars.
(ii.) Want of uniformity in the distribution of the proper motions.

To elucidate the extent of the uncertainty of the result which might be expected from these indications of systematic differences

istances of the stars in different parts of the sky, separate
nations are made in this section for—

Stars between definite limits of proper motion.
Stars of different magnitudes.
Stars of Types I. and II.

regards the formulæ to be used, the simple and con-
method introduced by Airy has been employed. If X
re the coordinates of the solar apex, then each proper
in right ascension leads to an equation of the form
$-Y \cos \alpha = \mu$; and each proper motion in north polar
to an equation of the form

$$X \cos \alpha \sin \delta + Y \sin \alpha \sin \delta - Z \cos \delta = -\mu'.$$

data on which the solutions are based are as follows :—
ars of extremely large proper motion have been entirely

the stars whose proper motions are greater than 20″ per
have been treated separately, equations of condition
tained for each star, and normal equations formed and

d further by the systematic corrections in R.A. given on o. All the quantities are given in terms of centennial proper ɔns.

'he general character of the normal equations is shown by 'ollowing example found for the 4001 stars whose proper ɔns are $<20''$, giving equal weight to each star :—

From Right Ascensions.

$$\left.\begin{aligned} 195{\cdot}8X + 24{\cdot}6Y &= -\;\;6''{\cdot}3 \\ 24{\cdot}6X + 205{\cdot}2Y &= -439{\cdot}0 \end{aligned}\right\}$$

From Declinations.

$$\left.\begin{aligned} 133{\cdot}8X - 12{\cdot}9Y - 43{\cdot}2Z &= -\;\;18''{\cdot}4 \\ -12{\cdot}9X + 122{\cdot}6Y + 16{\cdot}9Z &= -202{\cdot}9 \\ -43{\cdot}2X + 16{\cdot}9Y + 144{\cdot}4Z &= +168{\cdot}1 \end{aligned}\right\}$$

From Right Ascensions and Declinations.

$$\left.\begin{aligned} +329{\cdot}6X + 11{\cdot}7Y - 43{\cdot}2Z &= -\;\;24''{\cdot}7 \\ +\;11{\cdot}7X + 327{\cdot}7Y + 16{\cdot}9Z &= -641{\cdot}9 \\ -\;43{\cdot}2X + 16{\cdot}9Y + 144{\cdot}4Z &= +168{\cdot}1 \end{aligned}\right\}$$

General Solution. Proper Motions 0''–20''. 4001 *Stars.*

(Equal weights to each star.)

	X	Y	Z	M.	A.	D.
	''	''	''	''	°	°
R.A. ...	+0·33	− 2·00	...	...	276	...
Decl. ...	+0·13	− 1·85	+ 1·43	...	274	38
ınd Decl.	+0·19	− 1·90	+ 1·47	2·40	275	38

Proper Motions 0''–20''. 4001 *Stars.*

(Equal weight to equal areas.)

	X	Y	Z	M.	A.	D.
	''	''	''	''	°	°
R.A. ...	+0·13	− 2·30	...	...	273	...
Decl. ...	+0·01	− 1·90	+ 1·27	...	270	34
ınd Decl.	+0·09	− 2·09	+ 1·27	2·55	272	31

(i.) *Solutions according to Size of Proper Motion.*

(*a*). *Proper Motion* 0''–5''. 2885 *Stars.*

(Equal weight to each star.)

	X	Y	Z	M.	A.	D.
	''	''	'	''	°	°
R.A. ...	+0·13	− 1·04	...	...	277	...
Decl. ...	−0·07	− 0·70	+ 0·68	...	264½	44
ınd Decl.	+0·05	− 0·91	+ 0·74	1·17	273	39

(Equal weights to equal areas of the sky.)

	X.	Y.	Z.	M.	A.	D.
	″	″	″	″	°	°
From R.A. ...	+0·22	− 0·92	...	...	283½	...
„ Decl. ...	−0·02	− 0·81	+ 0·58	...	268½	35
R.A. and Decl.	+0·12	− 0·86	+ 0·58	1·08	278	34

(*b*). *Proper Motion* 5″–10″. 800 *Stars.*

	″	″	″	″	°	°
From R.A. ...	−0·04	− 3·68	...	...	269½	...
„ Decl. ...	−0·10	− 3·46	+ 2·61	...	268½	38½
R.A. and Decl.	−0·05	− 3·56	+ 2·69	4·47	269	37½

(*c*). *Proper Motion* 10″–20″. 316 *Stars.*

	″	″	″	″	°	°
From R.A. ...	+0·81	− 7·63	...	...	276	...
„ Decl. ...	−0·14	− 8·54	+ 3·33	...	269	21
R.A. and Decl.	+0·45	− 7·92	+ 3·20	8·36	273½	22

(*d*). *Proper Motion* > 20″. 163 *Stars.*

	″	″	″	″	°	°
From R.A. ...	+3·10	−21·83	...	...	278	...
„ Decl. ...	+0·67	−20·88	+12·62	...	272	31
R.A. and Decl.	+2·12	−21·51	+12·74	25·11	275½	30½

The stars from 10″–20″ give a very small value for D. When the above results are combined it is found that

$$D = 27^\circ \text{ from stars of p.m.} > 10''$$

and

$$D = 39^\circ \quad ,, \quad ,, \quad ,, \quad < 10''$$

(ii.) *Solutions for Stars of Different Magnitudes.*

A determination was made for stars brighter than $6^m{\cdot}5$, excluding those whose proper motion was greater than 20″ a century, and gave the following results :—

Stars of $6^m{\cdot}5$ *and brighter, p.m.* 0″–20″. 1382 *Stars.*

	X.	Y.	Z.	M.	A.	D.
	″	″	″	″	°	°
From R.A. ...	−0·05	−2·64	...	...	269	...
„ Decl. ..	+0·11	−2·14	+1·50	...	273	35
R.A. and Decl.	0·00	−2·47	+1·51	2·90	270	32

Rigorous solutions have not been made for the separate magnitudes, but the following rough determinations from the tables on p. 437 are of interest. Equal weight has been given to each octant, and the sine and cosine of the mean declination have been taken as 0·8 and 0·6. Stars of proper motion > 20″ a century have been omitted.

Mags. $1^m\cdot0$–$4^m\cdot9$. 200 *Stars.*

	X.	Y.	Z.	M.	A.	D.
	"	"	"	"	°	°
A. ...	−1·67	−2·72	...	...	232	...
cl. ...	−0·94	−3·76	+0·87	...	266	13
Decl.	−1·46	−3·02	+0·87	3·96	245	16

Mags. $5^m\cdot0$–$5^m\cdot9$. 454 *Stars.*

	X.	Y.	Z.	M.	A.	D.
	"	"	"	"	°	°
A. ...	−0·01	−2·83	...	...	270	...
cl. ...	−0·22	−2·86	+1·43	...	265½	26½
Decl.	−0·09	−2·84	+1·43	3·18	268	27

Mags. $6^m\cdot0$–$6^m\cdot9$. 1003 *Stars.*

	X.	Y.	Z.	M.	A.	D.
	"	"	"	"	°	°
A. ...	+0·52	−2·53	...	...	281½	...
cl. ...	+0·08	−2·02	+1·55	...	272	37½
Decl.	+0·36	−2·39	+1·55	2·85	278	33

Mags. $7^m\cdot0$–$7^m\cdot9$. 1239 *Stars.*

	X.	Y.	Z.	M.	A.	D.
	"	"	"	"	°	°
A. ...	+0·55	−1·88	...	...	286	...
cl. ...	−0·07	−1·50	+1·40	...	267½	43
Decl.	+0·32	−1·74	+1·40	2·24	280	38½

Mags. $8^m\cdot0$–$8^m\cdot9$. 811 *Stars.*

	X.	Y.	Z.	M.	A.	D.
	"	"	"	"	°	°
A. ...	− ·06	−1·81	...	...	268	...
cl. ...	+ ·27	−1·54	+1·57	...	280	46½
Decl.	+ ·06	−1·70	+1·57	2·32	272	43

most remarkable feature of the above table is the sive increase of D as fainter stars are taken. The ent of the results from right ascensions and declinations ghout satisfactory, so that there is no reason to suppose ult is due to any systematic errors of the observations.

results may be compared with those from Bradley's stars y Newcomb, "The Precessional Constant" (pp. 31 and

iii.) *Solutions for Stars of Spectral Types I. and II.*

stars of Type I. are obtained from the Draper Catalogue ained on p. 434.

Stars of Type I.

p.m. < 20″. Mean Mag. 6·3. 1100 Stars.

	X.	Y.	Z.	M.	A.	D.
	"	"	"	"	°	°
A.	+0·12	−2·48	...	...	273	...
cl.	−0·34	−1·85	+0·88	...	263	25
d result	−0·07	−2·25	+0·95	2·44	269	23

table on p. 434 shows how uniformly the stars of
. are distributed over the part of the sky with which we
erned. The proportion of stars between different limits
er motion is also very regular. On this account these
uld seem to be very suitable for a determination of the
n of the Sun's motion, as the natural inference from
mmetrical distribution both in numbers and proper
is that they are actually in space distributed symmetri-
th reference to the Sun.

Stars of Type II.

p.m. < 20″. Mean Mag. 6^{m}·2. 866 Stars.

	X.	Y.	Z.	M.	A.	D.
	″	″	″	″	°	°
A.	+0·05	−2·28	...	...	271	...
l.	+0·25	−2·20	+1·65	...	276	37
l result	+0·13	−2·23	+1·66	2·79	273	37

p.m. 20″–40″. 89 Stars.

	X.	Y.	Z.	M.	A.	D.
	″	″	″	″	°	°
A.	+1·0	−19·3	...	...	273	...
l.	+0·9	−20·0	+13·1	...	272½	33

values of the position of the apex of the Sun's way from the different groupings of the stars :

1. The systematic difference in the results given by stars of Type I. and Type II.
2. Faint stars give large values of A and D, while the brightest stars give small values.
3. The progressive values of D under the groupings arranged according to magnitude.
4. Large as compared with small proper motions give a small value of D.
5. The small value of D given by the group of stars limited to 10″-20″.

The different values of A and D are grouped in a table at the beginning of this paper (p. 429), and the value of the position of the apex of the Sun's motion assumed as most probable is

$$A = 275^\circ \qquad D = 37^\circ$$

Before leaving this subject it seems well once again to call attention to the effect of precession and systematic corrections on the values of the coordinates of the position of the apex of the Sun's motion. The relative effects will of course depend on the size of the proper motions under discussion ; but taking for this purpose the general solution of 4001 stars with centennial proper motions ranging between 0″ to 20″ the following results are due to

1. *Precession.*—The effect on D is small and uncertain, but on A considerable, thus :

Precession ...	A
	°
Struve-Peters ...	266
Adopted value ...	275
Newcomb ...	279

2. The systematic corrections in R.A. as given on p. 440.

diminish A between 2° and 3°
also D by 1°

3. A constant systematic error in the N.P.D.s would alter the value of Z by twice the error; thus a correction of 0″·1 would alter Z by 0″·2 and the value of D by 4°.

The following lists represent annual proper motions in arc, in R.A., and N.P.D. deduced directly from a comparison between the Groombridge and Greenwich Catalogues (the latter corrected to Newcomb's system for the purpose) with the Struve-Peters constants of precession.

List of Stars omitted on account of extremely great Proper Motion.

Name.	Magnitude and Spectral Type.		R.A.	N.P.D.	Annual Proper Motion R.A.	Annual Proper Motion N.P.D.
	m		h m	°	"	"
Groomb. 34 ...	8·3		0 10	46·8	+2·850	−0·378
η Cass. ...	3·7	II.	0 40	32·5	+1·100	+0·511
μ Cass. ...	5·3	II.	0 58	35·8	+3·375	+1·551
ι Pers.	4·2	II.	2 58	41·0	+1·243	+0·064
θ Urs. Mag. ...	3·3	II.	9 23	37·6	−0·934	+0·541
Groomb. 1618...	6·8	II.	10 2	39·8	−1·337	+0·515
Groomb. 1830...	6·5	I.	11 44	51·2	+3·985	+5·766
σ Drac. ...	4·8	II.	19 33	20·6	+0·558	+1·762
η Ceph. ...	3·6	II.	20 42	28·8	+0·109	−0·810

List of Stars whose Annual Proper Motion is greater than 0″·200.

β Cassiop. ...	2·4	II.	0 1	31·7	+·533	+·190
23 Androm. ...	5·6	II.	0 6	49·8	−·127	+·163
Groomb. 93 ...	7·4	I.	0 26	42·9	+·393	−·053
Groomb. 126 ...	7·9	II.	0 35	14·9	+·391	+·113
Groomb. 145 ...	7·6		0 40	20·4	+·500	−·217
θ Cass. ...	4·5	I.	1 2	35·7	+·234	+·037
Groomb. 295 ...	7·5		1 12	38·8	+·295	+·108
δ Cass. ...	2·8	I.	1 16	30·6	+·304	+·048
Gr. 307 ...	7·3	II.	1 17	16·6	+·202	+·128
ω Androm. ...	5·2	II.	1 19	45·4	+·327	+·099
Groomb. 356 ...	6·5	II.	1 30	44·9	+·221	+·234
Pi. I. 142 ...	5·0	II.	1 33	48·1	+·798	+·138
Pi. I. 159 ...	5·6	II.	1 37	27·0	+·583	+·227
54 Cass. ...	6·7	II.	1 56	19·2	+·301	+·240
6 Persei ...	5·4	II.	2 4	39·7	+·317	+·153
θ Persei ...	4·1	II.	2 34	41·4	+·346	+·097
κ Persei ...	4·0	II.	2 59	45·7	+·183	+·154
Pi. III. 28 ...	6·2	II.	3 11	41·5	+·212	+·064
Groomb. 706 ...	7·4	I.	3 25	47·6	+·148	+·152
Groomb. 717 ...	7·0	I.	3 29	48·0	−·178	+·115
Groomb. 745 ...	8·2		3 42	14·3	+·377	+·527
Groomb. 762 ...	7·8	II.	3 49	15·2	+·196	+·299
Groomb. 775 ...	7·7		3 54	20·9	+·099	+·283
Groomb. 807 ...	7·5		4 11	12·7	+·224	+·106
Groomb. 864 ...	7·3		4 31	48·2	+·549	+·409
Groomb. 884 ...	7·1	I.	4 41	44·4	+·387	+·563

Name.	Magnitude and Spectral Type.		R.A.	N.P.D.	Annual Proper Motion. R.A.	N.P.D.
	m		h m	°	″	″
Capella ...	0·2	II.	5 6	44·2	+·083	+·429
λ Aurig. ...	4·9	II.	5 9	50·0	+·522	+·654
18 Camelop. ...	6·5	II.	5 20	32·9	+·118	+·218
Groomb. 990 ...	7·8		5 26	38·7	−·543	−·113
Groomb. 986 ...	7·3	II.	5 27	15·5	+·185	+·173
Piazzi V. 146 ...	6·4	II.	5 29	36·6	+·007	+·511
Groomb. 1108...	7·4		6 3	33·0	−·204	+·194
Piazzi VI. 75 ...	5·7	II.	6 18	31·7	−·027	+·325
6 Lyncis ...	5·7	II.	6 21	10·3	−·057	+·602
Groomb. 1178...	6·6	II.	6 23	31·8	+·112	+·170
Groomb. 1216...	7·8		6 35	45·6	+·168	+·211
18 Lyncis ...	5·4	II.	7 3	30·1	−·094	+·258
Piazzi VII. 132	6·5	II.	7 31	9·4	−·488	−·051
Groomb. 1437...	6·5	II.	8 17	43·8	−·062	+·361
ι Urs. Maj. ...	3·1	I.	8 49	41·4	−·454	+·250
10 Urs. Maj. ...	4·0	II.	8 51	47·6	−·463	+·250
Groomb. 1514...	6·6	II.	8 57	51·1	−·206	+·015
Groomb. 1571...	7·3	II.	9 32	40·5	−·075	+·197
15 Leo. Min. ...	5·1	II.	9 39	43·3	+·193	+·092
υ Urs. Maj. ...	3·8	II.	9 40	30·2	−·306	+·161
Groomb. 1596...	8·0		9 51	33·7	−·192	+·455
Piazzi X. 31 ...	6·7	II.	10 10	45·2	+·079	+·294
Groomb. 1646...	6·5	I.	10 19	40·4	+·092	+·867
Piazzi X. 96 ...	7·6		10 25	40·0	+·263	−·140
Groomb. 1666...	6·9	II.	10 29	29·1	−·033	+·209
38 Leo. Min. ...	5·8	II.	10 31	51·3	−·228	+·045
{ Piazzi X. 135 ...	5·2	I.	10 35	43·0	−·288	+·087
{ Piazzi X. 137 ...	8·0		10 35	43·0	−·265	+·071
Groomb. 1697...	6·2	II.	10 43	19·4	−·388	+·079
47 Urs. Maj. ...	5·1	II.	10 51	48·7	−·340	−·054
{ Gr. 1744 ...	8·4		11 3	46·4	−·147	+·233
{ Gr. 1745 ...	7·3		11 3	46·4	−·139	+·249
Gr. 1766 ...	7·2	II.	11 12	37·4	−·174	+·102
Piazzi XI. 74 ...	5·9	II.	11 20	27·4	−·117	−·251
Groomb. 1794...	6·9		11 23	45·6	−·280	−·073
Groomb. 1795...	6·4	II.	11 23	41·2	−·242	+·071
Groomb. 1812...	6·7		11 30	44·0	−·594	−·015
Groomb. 1822...	7·7		11 38	41·5	−·568	+·292

...e.	Magnitude and Spectral Type.		R.A.	N.P.D.	Annual Proper Motion.	
					R.A.	N.P.D.
	m		h m	°	″	″
. Maj. ...	5·2	I.	11 54	46·1	−·333	−·079
b. 1855...	7·4		12 2	48·9	−·316	+·052
b. 1866...	8·9		12 9	25·5	−·269	−·073
1656 ...	6·4	II.	12 12	2·8	+·258	+·012
b. 1876...	8·0	II.	12 14	27·4	−·275	+·256
Ven. ...	6·2	II.	12 23	37·6	−·262	−·026
Ven. ...	4·3	II.	12 27	47·8	−·699	−·300
. Ven. ...	6·0	II.	12 38	49·9	−·379	−·138
Ven. ...	2·7	II.	12 49	50·9	−·243	−·050
b. 1947...	7·7	II.	12 53	20·4	−·278	−·262
XIII. 96	6·5	II.	13 21	26·0	−·398	−·223
b. 2021...	8·4		13 31	50·1	−·199	+·138
b. 2022...	7·8		13 31	50·1	−·210	+·131
XIII. 200	6·5	II.	13 40	33·3	+·098	+·360
b. 2068...	6·5	II.	13 53	27·8	−·019	−·210
is ...	4·2	I.	14 11	43·2	−·186	−·166

Name.	Magnitude and Spectral Type.		R.A.	N.P.D.	Annual Proper Motion. R.A.	Annual Proper Motion. N.P.D.
	m		h m	°	"	
Groomb. 2354...	7·0		16 26	41·7	−·109	+·295
Pi. XVI. 195 ...	6·6	II.	16 37	12·3	−·097	−·277
Groomb. 2389...	6·7		16 49	46·9	+·110	+·324
Groomb. 2391...	6·1	II.	16 50	12·2	+·058	−·212
Groomb. 2393...	7·0		16 53	27·7	−·345	+·052
h^1 Drac. ...	4·9	II.	16 55	24·6	+·250	−·051
26 Drac. ...	5·3	II.	17 33	28·0	+·233	+·509
ω Drac. ...	4·9	II.	17 38	21·2	+·016	−·333
30 Drac. ...	5·1	I.	17 45	39·2	−·059	−·207
{ ψ Drac. ...	4·8	II.	17 45	17·8	+·010	+·278
{ ψ^2 Drac. ...	6·2	II.	17 45	17·8	+·031	+·295
35 Drac. ...	5·1	II.	17 56	13·0	+·069	−·230
Groomb. 2527...	6·0	II.	18 7	35·8	+·128	−·250
Groomb. 2538...	6·2	II.	18 12	49·1	−·191	−·072
36 Drac. ...	5·1	II.	18 13	25·7	+·381	−·033
Groomb. 2571...	8·4		18 22	44·0	−·329	−·208
χ Drac. ...	3·7	II.	18 24	17·3	+·518	+·380
α Lyræ ...	0·1	I.	18 32	51·4	+·209	−·286
Groomb. 2624...	8·2		18 33	47·5	+·281	−·06
Groomb. 2630...	8·0	I.	18 34	26·4	−·062	+·252
Groomb. 2686...	7·2		18 46	51·6	+·317	−·027
Groomb. 2699...	5·6	II.	18 48	37·2	−·018	−·268
Groomb. 2789...	5·9	II.	19 8	40·4	−·170	−·620
Groomb. 2809...	6·0	II.	19 13	43·3	−·015	−·290
Groomb. 2867...	8·5		19 28	41·7	+·063	−·333
Piazzi XIX. 191	8·2		19 28	40·2	−·095	−·303
Groomb. 2875...	6·7		19 29	31·7	−·543	+·375
Piazzi XIX. 211	5·7	II.	19 30	39·1	+·015	+·208
θ Cygni ...	4·5	II.	19 32	40·1	−·011	−·240
{ c Cygni ...	5·9	II.	19 38	39·8	−·141	+·143
{ Brad. 2513 ...	6·2	II.	19 38	39·8	−·137	+·155
Groomb. 2961...	7·7		19 48	51·6	−·016	−·320
Groomb. 3012...	8·3		19 56	27·5	+·186	−·138
Groomb. 3042...	5·7	I.	20 2	37·3	+·211	−·256
Piazzi XX. 30...	8·8		20 4	26·7	+·194	−·157
Groomb. 3127...	8·2		20 13	40·2	−·230	+·206
Groomb. 3150...	6·0	II.	20 16	23·6	+·495	−·287
Groomb. 3215...	7·0		20 28	48·6	−·155	−·436

	Magnitude and Spectral Type.		R.A.	N.P.D.	Annual Proper Motion. R.A.	Annual Proper Motion. N.P.D.
	m		h m	°	"	"
. 3249...	6·9		20 34	48·3	−·085	+·216
. ...	6·1	II	20 38	9·4	+·096	−·207
XX. 332	4·7	II.	20 42	33·0	−·084	+·242
. 3357...	6·7		20 54	50·4	+·225	−·209
792 ...	5·5	I.	21 20	44·0	+·208	−·040
. 3477...	7·9		21 23	10·3	+·181	−·096
i ...	4·4	I.	21 59	26·1	+·212	−·065
. 3689...	8·6		22 1	37·6	−·532	−·341
926 ...	5·5	II.	22 6	33·9	+·249	−·140
i ...	4·2	I.	22 10	33·7	+·438	−·046
. 3794...	8·2		22 24	50·1	−·259	−·041
. 3843...	6·9		22 32	46·5	+·243	−·056
. 3848...	6·7	II.	22 33	39·7	+·201	−·047
m. ...	4·8	II.	22 57	40·8	+·144	−·169
m. ...	5·8	I.	23 3	47·3	−·198	+·192
084 ...	5·7	II.	23 10	37·6	+·103	+·259

Number of Stars in Group.	Mean R.A. of Group.		Mean N.P.D. of Group.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.
	h	m	°	″	″
22	7	8	20·7	−·001	+·019
40	8	14	20·8	−·012	+·027
14	9	48	20·7	−·030	+·025
21	11	8	21·3	−·008	+·013
26	12	56	20·2	−·027	+·006
25	14	9	21·4	−·009	−·008
31	15	42	20·4	−·004	·000
24	17	8	18·6	−·003	+·002
15	18	47	21·0	+·009	−·021
33	20	21	20·4	+·013	+·002
50	21	52	20·3	+·024	+·005
59	23	24	19·1	+·021	+·004

Zone 25°–35°.

Number of Stars in Group.	Mean R.A. of Group.		Mean N.P.D. of Group.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.
	h	m	°	″	″
46	0	39	30·0	+·017	+·010
28	1	33	28·3	+·019	+·010
13	2	21	32·9	+·018	+·002
17	3	33	29·0	−·002	−·003
21	4	27	30·2	+·011	+·029
30	5	40	31·5	+·005	+·031
48	6	29	31·6	−·003	+·020
38	7	35	31·4	−·009	+·026
19	8	36	28·6	−·015	+·019
20	9	35	30·5	−·015	+·006
22	10	36	31·4	−·039	+·016
26	11	30	30·5	−·023	−·004
32	12	30	29·8	−·015	−·010
17	13	30	31·5	−·008	+·005
18	14	35	30·2	−·029	+·007
33	15	28	29·9	−·017	−·007
21	16	32	29·4	−·002	−·012
9	17	19	29·6	+·019	−·036
34	18	40	30·5	+·003	−·017
40	19	36	30·8	+·017	−·009
63	20	30	31·2	+·010	−·006
68	21	38	29·5	+·016	−·008
53	22	40	30·4	+·025	+·003
45	23	31	29·6	+·010	+·005

Zone 35°–45°.

Number of Stars in Group.	Mean R.A. of Group.		Mean N.P.D. of Group.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.
	h	m	°	″	″
61	0	24	40·1	+·011	+·010
60	1	6	41·7	+·017	+·013
63	1	55	39·2	+·001	+·017
31	2	41	39·5	+·008	+·012
54	3	21	40·9	+·021	+·023
30	4	12	39·4	+·011	+·028
30	4	52	40·0	+·003	+·036
54	5	43	40·5	+·002	+·020
23	6	18	40·7	−·010	+·017
24	7	9	40·5	−·012	+·045
9	7	49	37·7	−·032	+·011
17	8	40	39·7	−·038	+·024
23	9	19	39·9	−·012	+·014
20	10	5	39·4	−·020	+·004
27	10	55	41·0	−·028	+·020
10	11	36	41·0	−·005	+·002
10	12	27	40·1	−·033	−·028
17	13	13	41·0	−·015	+·002
16	13	46	39·2	−·039	−·015
17	14	43	40·5	−·012	+·009
20	15	25	39·5	−·007	·000
22	16	13	39·9	−·016	−·001
7	16	45	40·0	−·023	−·026
23	17	47	42·3	−·007	+·010
48	18	24	40·5	+·004	−·007
67	19	11	40·0	+·004	+·004
63	19	57	40·1	+·005	−·007
90	20	37	39·4	+·011	+·002
65	21	24	39·0	+·008	−·002
92	22	7	38·9	+·009	+·006
71	22	49	39·7	+·019	+·007
64	23	41	39·5	+·017	+·013

Zone 45°–52°.

Number of Stars in Group.	Mean R.A. of Group.		Mean N.P.D. of Group.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.
	h	m	°	″	″
33	0	16	47·0	+·006	+·014
31	0	47	47·7	+·013	+·021

Mean R.A. of Group.	Mean N.P.D. of Group.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	Number of Stars in Group.	Mean R.A. of Group.	Mean N.P.D. of Group.	Mea[n Proper Motion] R.A.
h m	°	″	″		h m	°	″
1 17	47·5	+·017	+·022	8	12 50	48·1	−·04
1 48	48·7	+·009	+·024	21	13 15	49·3	−·04
2 12	48·8	−·016	+·018	14	13 45	48·1	−·03
2 46	48·7	+·004	+·031	19	14 16	49·1	−·02
3 18	47·6	+·017	+·017	13	14 42	48·8	−·03
3 40	48·5	+·003	+·013	14	15 19	48·7	−·01
4 20	48·3	+·004	+·026	8	15 45	48·1	−·01
4 50	48·4	+·004	+·016	8	16 15	49·0	−·02
5 19	49·0	−·005	+·023	9	16 46	48·2	−·02
5 49	47·9	+·004	+·034	8	17 15	50·0	−·01
6 19	48·4	−·009	+·020	30	17 47	48·2	−·00
6 47	48·5	−·012	+·031	42	18 18	48·5	−·00
7 16	49·7	−·021	+·024	81	18 46	48·8	−·01
7 50	47·1	−·021	+·012	42	19 16	48·6	+·00
8 21	47·8	−·030	+·029	77	19 46	49·2	−·00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Zone 15°–25°.

Limits of R.A.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	No. of Stars.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	No. of Stars.
h h	"	"		"	"	
0– 3	+·023	+·012	43	+·021	+·022	21
3– 6	+·018	+·023	25	+·014	+·009	13
6– 9	−·025	+·035	13	·000	+·017	23
9–12	−·019	−·005	11	−·007	+·027	12
12–15	+·005	·000	12	−·042	·000	21
15–18	−·010	−·012	15	−·007	−·003	16
18–21	+·008	−·006	13	+·016	−·004	15
21– 0	+·027	−·003	38	+·024	+·014	22

Zone 25°–35°.

Limits of R.A.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	No. of Stars.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	No. of Stars.
0– 3	+·022	+·012	25	·000	+·002	19
3– 6	+·004	+·024	22	+·001	+·020	19
6– 9	−·007	+·012	35	−·018	+·039	30
9–12	−·029	−·002	15	−·026	+·012	35
12–15	−·001	−·005	24	−·021	+·004	19
15–18	+·019	−·014	17	−·024	−·017	15
18–21	+·010	−·015	30	+·023	−·022	24
21– 0	+·017	·000	54	+·012	+·001	26

Zone 35°–45°.

Limits of R.A.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	No. of Stars.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	No. of Stars.
0– 3	+·010	+·012	85	+·012	+·024	40
3– 6	+·012	+·028	72	+·016	+·033	28
6– 9	−·029	+·020	19	−·015	+·031	26
9–12	+·004	−·004	20	−·036	+·008	23
12–15	−·035	−·018	20	−·023	−·004	18
15–18	−·006	+·003	26	−·022	+·009	20
18–21	+·012	−·001	54	−·004	+·001	43
21– 0	+·011	+·009	53	+·020	+·005	34

Zone 45°–52°.

Limits of R.A.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	No. of Stars.	Mean Proper Motion. R.A.	Mean Proper Motion. N.P.D.	No. of Stars.
0– 3	+·023	+·021	41	−·018	+·025	22
3– 6	+·004	+·022	41	+·014	+·031	26
6– 9	−·006	+·022	24	−·025	+·029	37
9–12	−·060	+·020	18	−·061	+·006	19
12–15	−·064	−·021	17	−·039	+·009	22
15–18	−·027	−·025	17	−·008	−·014	31
18–21	+·003	+·003	56	−·002	−·001	27
21– 0	+·018	+·012	55	+·031	+·006	12

e Determination of Selenographic Positions and the Measurement of Lunar Photographs.

[Fourth Paper.]

'irst Attempt to Determine the Figure of the Moon.

By S. A. Saunder, M.A.

§ 1. *Introduction.*

he third paper of this series (*Memoirs R.A.S.* vol. lvii.
 have given the places of 1433 points as determined
 measures of four Paris negatives, the reductions being
 the supposition that the points all lie on the surface of
. But one of the results I hope will follow from the
s on which I am engaged is a determination of the true
 the Moon; and although the work is at present incom-
d the plates already measured are, when taken by them-
ot very well suited for such a determination, I have wished
hether the results obtained are such as to justify a hope
s object may be ultimately accomplished.

as first pointed out by Newton that if the Moon were

above "the mean sphere" by the radius of the Moon, it seems to me to represent a smaller quantity than the excess of the greatest radius over the least. If the greatest radius is really that towards the Earth, the mean of these twenty radii must be less than the greatest; whilst no reason is given for supposing that the radius of the mean sphere is less than the least radius of the Moon (*Harvard Annals*, vol. li. p. 38).

More recently still Hayn in *Ast. Nach.* No. 3956, assuming that *Mösting A* is on the mean surface, finds an elongation of 4000 metres, giving an elongation ·0023. But he points out that this assumption cannot be proved.

The value obtained in the present paper is ·00052±·00027. This determination is made from a consideration of the absolute altitudes of thirty-eight points measured on each of four negatives, and all situated near the central meridian. The probable error is considerably less than that of any previous determination with which I am acquainted; but although I do think that it shows that the elongation is very small, I do not wish to lay any great stress on the actual result itself. The number of points employed is small, and the individual altitudes are subject to considerable uncertainty. My desire is rather to give grounds for my opinion that the method adopted is one of considerable promise.

§ 2. *Theory of the Method of Determining Absolute Altitudes and of the Apparent Change of Position of a Point under Different Librations.*

The theory of the method I purpose to adopt may be stated as follows:—

Let M be the centre of the Moon.

E the point of observation.

S a point whose altitude is to be determined.

Let the radius MS cut a "mean sphere" whose surface nearly coincides with that of the Moon in B.

Let ES cut the same sphere in P.

In the method of reduction which I have adopted, as well as in that adopted by Dr. Franz, it is assumed that all the observed points are on the surface of a sphere. Suppose this to be the sphere whose radius is MB, then the reduced coordinates ξ, η are those of P.

Let M be taken as origin.

ME as axis of z.

x, y, z the coordinates of P.

$x+\delta x$, $y+\delta y$, $z+\delta z$ those of B.

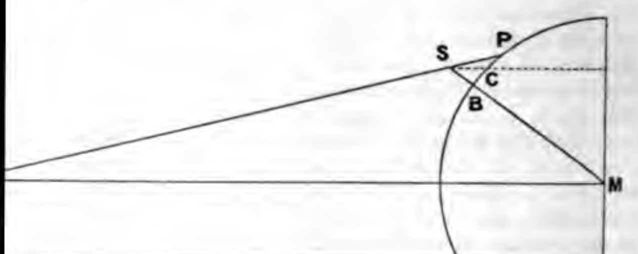
t $MB = 1$, $ME = d$, $BS = h$.
e coordinates of S are

$$(x+\delta x)(1+h),\ (y+\delta y)(1+h),\ (z+\delta z)(1+h).$$

e coordinates of E are

$$0,\ 0,\ d.$$

the three points E, S, P are in a straight line, $\therefore$ their pro-
s on any one of the coordinate planes are in a straight line.



re get

$$\delta x = -\frac{xzh'}{z-\sin s'}$$

$$\delta y = -\frac{yzh'}{z-\sin s'}$$

$$\delta z = \frac{h'(1-z^2)}{z-\sin s'}$$

If now ξ, η are the coordinates of P referred to the standard xes

$$\xi+\delta\xi,\ \eta+\delta\eta \text{ those of B}$$

re have

$$\xi = Ax+By+Cz, \quad \eta = Dx+Ey+Fz$$

rhere the direction cosines A, B, C, D, E, F have the values lefined in *Monthly Notices R.A.S.* vol. lx. p. 187,

nd

$$\delta\xi = A\delta x+B\delta y+C\delta z, \quad \delta\eta = D\delta x+E\delta y+F\delta z.$$

$$\therefore\ \delta\xi = \frac{C-\xi z}{z-\sin s'}h' = Ph' \text{ say} \ldots \qquad (1)$$

$$\delta\eta = \frac{F-\eta z}{z-\sin s'}h' = Qh' \text{ ,,} \ldots \qquad (2)$$

f now ξ_1, η_1 are the values of ξ, η given by any particular plate,

P_1, Q_1 the corresponding values of P, Q,

$\bar{\xi}$, $\bar{\eta}$ the mean of the values given by all the plates,

$\bar{\xi}+\delta\bar{\xi}$, $\bar{\eta}+\delta\bar{\eta}$ the coordinates of B,

re have the following conditional equations from which to find ξ, $\delta\bar{\eta}$, and h :

$$\bar{\xi}+\delta\bar{\xi} = \xi_1+P_1h'$$

$$\bar{\eta}+\delta\bar{\eta} = \eta_1+Q_1h'$$

rith similar equations for each of the other plates.

These equations may be written

$$\delta\bar{\xi}-P_1h'+(\bar{\xi}-\xi_1) = 0$$

$$\delta\bar{\eta}-Q_1h'+(\bar{\eta}-\eta_1) = 0$$

he solution by least squares is much facilitated if we notice that y definition of $\bar{\xi}$, $\bar{\eta}$

$$\Sigma(\bar{\xi}-\xi_1) = 0,\ \Sigma(\bar{\eta}-\eta_1) = 0$$

nd therefore, if n be the number of plates, the normal equations ecome

$$n\delta\bar{\xi}-\Sigma P_1h' = 0$$

$$n\delta\bar{\eta}-\Sigma Q_1h' = 0$$

$$-\Sigma P_1 \,.\, \delta\bar{\xi}-\Sigma Q_1 \,.\, \delta\bar{\eta}+\Sigma(P_1^2+Q_1^2)h'-\Sigma\{P_1(\bar{\xi}-\xi_1)+Q_1(\bar{\eta}-\eta_1)\} = 0$$

l solution being

$$\delta\bar{\xi} = \frac{1}{n}\Sigma P_1 \,.\, h', \text{ with weight } n \ldots \quad \ldots \quad \ldots \quad (3)$$

$$\delta\bar{\eta} = \frac{1}{n}\Sigma Q_1 \,.\, h', \text{ with weight } n \ldots \quad \ldots \quad \ldots \quad (4)$$

$$h' = \frac{\Sigma\{P_1(\bar{\xi}-\xi_1)+Q_1(\bar{\eta}-\eta_1)\}}{\Sigma(P_1^2+Q_1^2)-\frac{1}{n}\{(\Sigma P_1)^2+(\Sigma Q_1)^2\}} \ldots \quad \ldots \quad (5)$$

ominator of the last fraction being also the weight of h'

$$h = \frac{h'}{1-h'}$$

uracy at present obtained does certainly not require that tion should be extended to include terms of the order c.

coordinates which have been tabulated in the catalogue values of $\bar{\xi}$, $\bar{\eta}$; these depend, not only on the position of t, but also on the librations of the particular plates from hey are determined. It is clear that, when the observan be made with sufficient accuracy, we should tabulate

constants of the plate described in my third paper (*Memoirs R.A.S.* vol. lvii. p. 5). It is therefore a function of the radii drawn to the crests of the walls of all the craters taken as standard points. The altitude found for any particular crater will be that of its crest above or below this mean sphere. I shall eventually assume that a smoothed surface drawn through all these crests will give us an approximation to the figure of the Moon.

§ 3. *Results obtained in the Determination of Absolute Altitudes.*

This preliminary discussion will be confined to the thirty-eight points which have been measured on all four plates, and which are therefore necessarily in the neighbourhood of the Moon's principal meridian. Fourteen of these points have also been measured by Dr. Franz on each of five plates, and I have treated his measures of these fourteen points, as given in *Breslau Mitteil.* vol. i., in precisely the same manner as my own.

The results obtained are exhibited in the following table, where

The first column gives the reference number to the formation as recorded in the complete catalogue.

The second column gives the name of the formation.

The third and fourth columns give its approximate position in selenographical coordinates.

The fifth column gives the absolute altitude found from the measures, with its probable error. These are expressed in terms of a unit equal to Moon's radius $\times 10^{-5}$, which is about 57 feet.

The sixth column gives the corresponding quantities as deduced from Dr. Franz's measures.

The seventh column requires some explanation. The mean altitude of the fourteen points, which both Dr. Franz and I have measured, is $+5$ units according to my measures, and $+175$ units according to Dr. Franz's. This may be taken to mean that the two altitudes are not referred to the same mean sphere, the radius of Dr. Franz's being 170 units less than mine. I have therefore subtracted 170 units from Dr. Franz's altitudes in order to refer them to the same sphere as mine, and the seventh column contains the excess of my altitude over his when so referred. A more complete discussion of the questions involved will be given in the next section.

The eighth and ninth columns contain the probable errors of ξ and η, as determined from the residuals before the correction for altitude is applied. ξ, η here denote the quantities represented by $\bar{\xi}$, $\bar{\eta}$ in § 2, or the coordinates of the mean position of P in fig. 1.

The tenth and eleventh columns contain the corresponding probable errors after the correction for altitude has been applied. ξ, η here denote the quantities represented by $\bar{\xi}+\delta\bar{\xi}$, $\bar{\eta}+\delta\bar{\eta}$ in § 2, or the coordinates of the point B in fig. 1.

3	4	5	6	7	8	9	10
Approximate Position.		Absolute Altitude and Probable Error.		Difference of Computed Altitudes.	Probable Errors ordinates. Before Correction for Altitude.		After Al
ξ	η	S.A.S.	J.F.	S−(F−170).	ξ	η	ξ
·023	−·832	− 89 ± 21	...	...	± 8·3	± 4·7	± 2·
·021	−·810	− 63 ± 39	...	...	8·7	6·4	5·
·023	−·804	− 57 ± 36	...	...	4·9	8·3	2·
·038	−·718	−163 ± 51	...	...	12·2	7·4	4·
·083	−·635	−110 ± 28	...	...	3·8	5·9	1·
·057	−·635	− 57 ± 113	...	...	7·8	18·7	7·
·056	−·615	− 49 ± 47	...	...	4·1	7·6	3·0
·066	−·453	−120 ± 69	...	...	10·8	4·3	9·6
·030	−·440	−311 ± 50	...	...	13·7	7·7	6·3
·035	−·401	−283 ± 65	...	...	13·6	8·1	5·4
·079	−·368	− 11 ± 26	+ 115 ± 59	+ 44	1·0	3·6	0·9
·024	−·309	−265 ± 76	...	...	9·8	11·6	1·7
·115	−·261	−115 ± 48	...	...	4·9	6·5	4·2
·014	−·148	−148 ± 65	+ 55 ± 55	− 33	7·1	7·6	4·8
·056	−·132	+ 27 ± 76	...	...	4·7	8·9	5·1
·038	−·121	+ 60 ± 37	...	...	3·8	3·7	2·5

§ 4. *Discussion of Results.*

The mean of the probable errors of the altitudes, whether determined from Dr. Franz's measures or my own, is a little over half a mile. As many of the actual errors may be expected to exceed this, the individual altitudes must be taken as subject to considerable uncertainty. The same conclusion may be drawn from an inspection of the seventh column.

In order to compare the altitudes deduced from Dr. Franz's measures with those deduced from my own it is necessary to know, first, the level of that part of the crater to which each set of measures applies, and, secondly, the radius of the mean sphere to which each set is referred. Dr. Franz, discussing the first point with regard to his own measures (*Die Figur des Mondes*, p. 26), comes to the conclusion that the observed point lies on the average on the same level as the surrounding country. I have already stated that in my measures the observed point must be taken as lying on the same level as the crest of the crater. On this account, therefore, my altitudes should on the average exceed Dr. Franz's by the average height of the crest of a crater above the surrounding country.

With regard to the second point I believe that the radius of the sphere to which Dr. Franz refers his points is that given by the equation $\sin s = \sin \pi \times \cdot 272410$ (*Die Figur des Mondes*, p. 9, and *Breslau Mitteil.* vol. i. p. 5). So far as I am able to determine the radius of my mean sphere from data given in this paper it exceeds $1\cdot 00079$ of that given by the equation $\sin s = \sin \pi \times \cdot 272536$ by the average height of the crest of a crater above the mean surface (see § 7).

If we subtract this average height from the radius of my mean sphere we may then suppose that my measured altitudes are those of points on the same level as those measured by Dr. Franz, and, according to the figures just given, the radius of my sphere would be $1\cdot 00125$ of that adopted by Dr. Franz. This would make the radius of Dr. Franz's sphere 125 of the units adopted in the table less than mine, which agrees with the systematic difference of 170 units as nearly as could be expected when the great uncertainty of the determinations is considered.

The individual differences given in the seventh column would be to some extent affected by the actual heights of the walls of the individual craters, but it does not seem worth while to discuss this any further. The mean value of the differences, considered without regard to sign, is ± 70 units.

It is unfortunate for the purposes of altitude determination that four plates now measured have all positive libration in latitude, though the librations in longitude are well separated. The result of this is that the conditional equations in η, those derived from equation (2) in § 2, have very little effect upon the solution which depends almost entirely upon those in ξ derived from equation (1). This, however, will correct itself in subsequent

the plates I propose to measure next have all negative
in latitude.

'ranz's five plates exhibit a greater variety of librations,
in this respect better adapted than my four for
ing altitudes. This is shown by a comparison of the
of the respective determinations. Taking the weight
dinate as determined from a single plate as the unit,
ht of a complete altitude determination from my four
lls as low as 0·026 for *Hipparchus H*, which is very
ably situated, but the determinations for a number of
ar the centre of the disc had weights 0·039 and 0·040,
r Dr. Franz's plates the lowest value found was 0·075.

304 residuals on which my determinations of these thirty-
itudes depend are those given in the catalogue, except
this purpose the telescopic measures are omitted and fresh
d residuals have therefore been found for the five points
by this omission. An examination of these residuals
at only four of them exceed 0″·5, and that the mean value
absolute magnitudes, considered without regard to sign,
3.

re therefore dealing with quantities of the same order as
which the known stellar parallaxes depend, and we have
g very different from stellar points to measure. It is

those given for some of the same craters in *Die Figur des Mondes*; these last depend upon a smaller number of measures made upon the same plates as were used for the measures given by Dr Franz in *Breslau Mitteil.* vol. i., and for several reasons seem to me to be less trustworthy than these later measures.

§ 5. *Consideration of the Points whose Apparent Positions are most affected by Change of Libration.*

Professor W. H. Pickering has devoted Chapter IV. in *Harvard Annals*, vol. li., to a consideration of the absolute altitudes of twenty points as deduced from Dr. Franz's measures, and bases his selection of these points on the dictum that "the proposed method of determining altitudes can be applied to most advantage to points situated near the centre of the disc." He gives no reason for this statement, which appears to me to be open to considerable doubt.

There can be no question of the geometrical fact that the displacement which the apparent selenographic position of a point can undergo for a given change of libration increases from the centre to the limb.

Thus let M be the centre of the Moon,

AC a mountain at the mean centre of the disc,

BD a mountain of equal height at B.

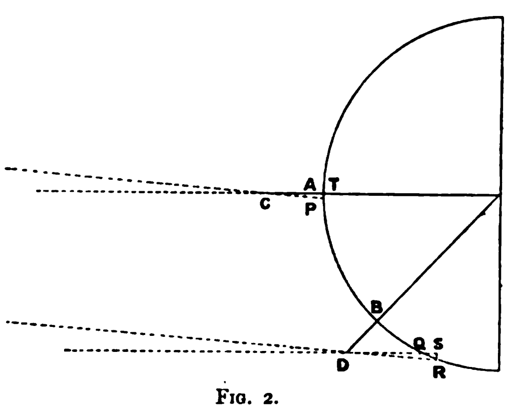


Fig. 2.

If for simplicity we suppose the Earth to be at an infinite distance, then under mean libration the point C will be referred to A on the mean sphere, and D to Q, where DQ is parallel to CA.

v the Moon be librated through an angle ACP in the
\B, so as to obtain the maximum in displacement of Q,
referred to P, and D to R where the angle QDR = the
:P.

Draw PT perpendicular to MA
and RS ,, DQ

PT, RS will be the computed displacements of C D
ely, and

RS : PT :: DR : CP
:: sec BDR : sec ACP nearly.

lifference between RS and PT will be increased if we
or the finite distance of the Earth.
the effect upon points near the limb is greater than
near the centre is shown in the weights of the altitudes
e from 0·026 for *Hipparchus H* to 0·342 for *Anaxagoras*.
eral expression for these weights is given in § 2, equa-
it depends only on the librations and the position of
t measured. The fact that the probable errors of the
ations, as shown in the fifth column of the table, do not

The equation to the mean surface of the Moon is thus

$$\frac{x^2+y^2}{(1-q)^2}+\frac{z^2}{(1-q+p)^2}=1$$

Neglecting squares of p and q this reduces to

$$(x^2+y^2+z^2)(1+2q)-2pz^2=1$$

Now referring to fig. 1 :

If x, y, z are the coordinates of S on the mean surface
ξ, η, ζ are the coordinates of the corresponding point B on the mean sphere
$BS = h$

Then

$$x=\xi(1+h), \qquad y=\eta(1+h), \qquad z=\zeta(1+h)$$

Hence

$$(\xi^2+\eta^2+\zeta^2)(1+h)^2(1+2q)-2p(1+h)^2\zeta^2=1$$

The values of h given in the table have to be multiplied by 10^{-5} in order to express them in terms of the Moon's radius ; we may therefore neglect their squares.

Doing this and remembering that

$$\xi^2+\eta^2+\zeta^2=1$$

we get

$$p\zeta^2-q-h=0 \qquad \dots \qquad \dots \qquad \dots \qquad (6)$$

The coordinates ξ, η tabulated in the catalogue apply to the point P, fig. 1 ; they must therefore be corrected by the addition of the quantities denoted in § 2, equations (3), (4), by $\delta\xi$, $\delta\eta$, and corresponding values of ζ^2 computed. Each of the thirty-eight points now gives a conditional equation of the type (6) for the determination of p, q.

These equations were formed and weighted by multiplying each by $\frac{1}{10^3\,\epsilon}$ where ϵ is the probable error of the corresponding value of h.

Normal equations were formed, and solved and the residuals from all the conditional equations computed.

The solution gave

$$p = +\cdot 00043 \pm \cdot 00030$$
$$q = +\cdot 00078 \pm \cdot 00022$$

But on applying Peirce's criterion it appeared that the equation due to *Purbach A* should be rejected. Its residual was

32, whilst the criterion gave $10^{-5} \times 472$ for the limit. ction here seems entirely justifiable. The value found ltitude may be erroneous, but the point certainly lies the position found for it is so much below the mean iven by the other points that it ought not to be employed ermination of the mean surface of the Moon from a few ly.

ting this point and solving again it was found that

$$p = +\cdot00052 \pm \cdot00027$$
$$q = +\cdot00079 \pm \cdot00019$$

efore

$$\frac{1-q+p}{1-q} = 1\cdot00052 \pm \cdot00027$$

smallness of p and q justifies the neglect of the squares.

7. *Provisional Determination of the Radius of the "Mean Sphere."*

The value now found is less than one-half of this, and the probable error less than one-fourteenth of that of the previous determination.

The determination now made applies only to a particular meridian, whilst Dr. Franz's points were distributed over the Moon. It is almost certainly possible to fit an ellipse on to a particular meridian with greater exactness than a spheroid could be fitted on to the whole surface, and this will probably account for part of the diminution in probable error. If sufficient material can be obtained, it will perhaps be well to attempt to determine the figure of the Moon by determining a number of sections in the way here attempted for the central meridian.

A part also of the improvement may be attributed to the fact that Dr. Franz's constants depend on measures of the limb. He himself attributes some of the discordances in his results to this cause, and in his subsequent work he seems to have altogether abandoned such measures.

My own experience, independently obtained, has been similar to his (*Monthly Notices R.A.S.* vol. lxii. p. 42).

It is interesting to note that the values of the moments of inertia of the Moon obtained by Dr. Franz in his discussion of the "Physical Libration" were such as would belong to a homogeneous ellipsoid with its principal axes in the ratios 1·0003 : 1 : ·9997, giving for the principal meridian an elongation ·0006, which agrees closely with that here found (*Die Figur des Mondes*, p. 2).

A difficulty in interpreting the present result arises when we notice that $1-q+p<1$, or that the longest radius of the Moon is less than that of my mean sphere. This might be explained by supposing that the craters used as standard points had on the whole higher walls than the thirty-eight here considered. But it was found in § 3 that the mean altitude of the fourteen points measured by Dr. Franz and myself was 5×10^{-5} of the Moon's radius above my mean sphere, so that the mean sphere would seem to pass pretty nearly through these points. And, moreover, the amount of this defect from unity is only 27×10^{-5} of the Moon's radius, which is just equal to its probable error. The true explanation is, I think, that the accidental irregularities of the surface are considerably greater than the elongation.

The comparison of the altitudes of the same fourteen points with those found by Dr. Franz seemed to indicate that the radius of his mean sphere was 170×10^{-5} of the Moon's radius less than mine, which would make it less than the least radius of the figure now determined for the Moon; but I hope that many of these small discordances will be considerably modified when we have better determinations of the altitudes.

The smallness of the elongation now found partly disposes of

lty I had felt in combining the measures made on
plates. It was impossible to use the same set of
points for all the plates : those illuminated in one were
he terminator in another, and there was therefore no
e that the measures were all referred to the same mean
Had the elongation been considerable the radius of the
here would have been sensibly affected by the distances
andard points from the mean centre of the disc, and a
correction would have been necessary.

means of these distances are not very different for the
plates, and I do not think that any sensible error is
ed in this way. It may become more important in
consider the actual heights of the walls of the different
nd the general level of the part of the surface on which
situated.

general result of the inquiry would seem to justify the
h which it was undertaken, and to show that the method
considerable promise. But, in spite of the reduction in
able error, it is not safe to place too much reliance on
erical results here obtained. A glance down the figures
titude column of the table in § 3 will show that while
eral level of the surface falls as the central meridian
he Mare Imbrium it rises again in the neighbourhood

part of the work has been accomplished by the help of grants received from the Government Grant Committee of the Royal Society, to whom I wish here to express my gratitude. If it is to be continued on the same scale it can only be by means of further assistance from the same source, and it seemed very desirable that an effort should be made at the earliest possible opportunity to ascertain to what extent the investigation is likely to increase our knowledge of the Moon.

There is another reason why the attempt should be made to determine the individual altitudes with all possible precision. It has been frequently suggested that measures of well-defined points upon the Moon's surface should be made with meridian instruments, instead of measures of the limb, in order to determine the position of the Moon. In order to compute the apparent position of a point on the surface relatively to the centre of the disc at any given instant it is necessary to know its selenographical coordinates in all three dimensions if full advantage is to be obtained of the increased accuracy of which I believe the method to be capable.

The same knowledge will be required if we are to adopt photographic methods of determining the Moon's position as has been proposed by Professor Turner (*Monthly Notices R.A.S.* vol. lxiv. p. 19).

The Spectroheliograph of the Solar Physics Observatory.

By William J. S. Lockyer, M.A., Ph.D., F.R.A.S.

Introduction.

Since the year 1897 numerous experiments have been made at this observatory to determine the best design for a spectroheliograph based on the Hale-Deslandres principle. The improvised instruments took many forms during the course of the trials, until finally, in 1901, the definite form resulting from these experiments was decided upon and the instrument purchased.

In the present paper it is proposed to describe somewhat in detail the instrument now at work, and give a brief account of some of the first results which have been obtained during the past year.

The principle of the spectroheliograph may first be described briefly. Imagine an ordinary student's spectroscope with a collimator and observing telescope, but with the addition of a plane mirror in the optical train to render the collimator and telescope parallel to each other. Replace the eyepiece of the observing telescope by a slit (secondary), thus providing a means of isolating any small portion of the spectrum. If now an image of the Sun fall on the slit (primary) forming part of the

or, then the light passing through the secondary slit will
sist of a small part of the spectrum corresponding to the
lth. By adjusting the secondary slit so that only one
the spectrum, such as H_β, is allowed to pass through it,
have an image in hydrogen light of that part of the
age that is passing between the jaws of the primary

oving the primary slit, and with it the whole spectro-
ross the solar image, different strips of the latter pass
ively through the collimator, and consequently corre-
strips in hydrogen light will find their way through
ndary slit. If the solar image be kept stationary, a
otographic plate placed nearly in contact with the
y slit, and the whole spectroscope moved parallel to the
the slit plates and in an east-and-west direction
ally, a picture of the Sun is built up in hydrogen light on
tive plate.

form of instrument in which the solar image and
phic plate are kept stationary is perhaps almost the
There is no restriction to the size or weight of the
eliograph, for the only motion required is that in
ntal direction, and this can be secured without great

The Siderostat.

This instrument does not differ in the main from an ordinary Foucault's siderostat except in point of size. It was constructed by Messrs. T. Cooke & Sons, York.

The massive base (6 feet $3\frac{1}{2}$ inches × 3 feet 1 inch) is supported on three large screw-heads each of which rests on a circular iron plate embedded in concrete. On the north side an antagonistic screw arrangement is attached to allow of an adjustment of the base in azimuth. The highest portion of the instrument is 7 feet $4\frac{1}{2}$ inches from the surface of these plates, while the centre of the horizontal axis on which the mirror moves is 4 feet $5\frac{3}{8}$ inches from the same level. The mirror itself is 18 inches in diameter and $2\frac{7}{8}$ inches thick, and was ground by the late Dr. Common. The mirror, cell, and projecting arm are counterbalanced by two levers carrying weights the ends of which are fitted at the back of the cell, two points in the mirror fork being used as a fulcrum for each. The driving clock is of the ordinary Cooke construction, and the weights are suspended over strong wooden gallows fitted close to the north side of the instrument. The clock is fitted with a Russell control, and this is operated from the spectroheliograph room by an electric pendulum made by Sir Howard Grubb. A four-volt cell is used to drive the pendulum, while two cells of four volts each supply the sparking current which operates the controlling armature.

The same two cells are also employed for actuating the two small motors connected by tooth-wheeled gear with the right ascension and declination axes for supplying slow motions in these two coordinates. The switchboard for this is situated in a convenient position on the concrete pillar supporting the spectroheliograph plate-carrier, together with the north foot of the fixed triangular framework, in order that the observer at the secondary slit can adjust the solar image in relation to the primary slit.

To inform the observer when the siderostat driving clock requires re-winding, an automatic electric arrangement rings a warning bell in the spectroheliograph house.

The instrument is sheltered in a wooden house the upper portion of which is on wheels, and can be moved on rails towards the north when necessary.

The Object-glass.

When the instrument was first set up a 6-inch Taylor lens of 20 feet focal length was employed, but this has been replaced by a 12-inch photo-visual Taylor objective having a focal length of 18 feet. It is mounted in a metal cell which is carried by a stout vertical mahogany frame fitted with a vertical adjustment for raising or lowering the object-glass, and adjustable in a horizontal direction for focussing purposes. This frame forms

a strong base resting on a concrete pillar. The object- to the south of the siderostat at a distancs of 40 feet and forms an image of the Sun of $2\frac{1}{8}$ inches diameter rimary slit plate.

The Spectroheliograph.

Slits.—The primary slit was made by Messrs. Ottway aling (Plate 9, fig. 1). It is constructed of brass, and ight jaws of platinum-iridium 3 inches in length. ws are mounted on two small arms pivoted at their points so that the milled-headed screw by which the f the slit is varied operates both jaws simultaneously. plate is mounted at one end of a brass tube, and is of rotation in a vertical plane; there is, further, an nt for focussing by which this tube can be moved in of the collimator tube, the different positions being read n attached scale. Behind the slit, but operated from he brass tube to which it is attached, is a small exposing On the slit plate itself a temporary artificial dust mark improvised consisting of a needle the point of which adjusted by means of a screw to just cover a small part

ment for photographing sun-spot spectra when a large grating becomes available, the two slit plates with the metal slides can be removed entirely from the metal-carrier, and easily replaced afterwards, without deranging any of the previous adjustments of the position of the slit relative to any particular spectrum line.

The jaws of the slit are $3\frac{1}{2}$ inches long and curved to a radius (48·38 inches), corresponding to the curvature of the "K" line of calcium.

Professor Hale, in the description of the Rumford spectroheliograph, adopted the method of dividing the curvature equally between the primary and secondary slits. A careful examination of the images formed by the South Kensington instrument has shown that any distortion which might arise from the method there in use is so inappreciable that it may practically be considered to be non-existent.

In order to allow the photographic plate to be placed nearly in contact with the slit plates, and clear of all projections, every part of the mounting and screw adjustments of the latter are retained on the tube side of the plane of these plates.

The Plate-carrier.

The plate-carrier, which was made by Messrs. Watson & Sons, consists of a vertical framework of mahogany carrying a second framework of similar wood sliding in grooves and capable of adjustment in a vertical direction, the clamping being performed by means of a milled nut (Plate 9, fig. 1). The whole of this framework has a strong mahogany base fitted with three levelling screws, resting on another mahogany base connected by rack and pinion to a heavily weighted box placed on a concrete pillar. The dark slides, made of mahogany and aluminium, are inserted horizontally in grooves on the vertical framework.

The draw slide is of thin aluminium, and fits in aluminium grooves. The inner portion of the dark slide is specially constructed so that the film side of the photographic plates is as close to the slide as possible. This is imperative, since the jaws of the secondary slit and the film of the photographic plate must be placed as near together as is practically possible.

The Optical Parts.

The two slits to which reference has just been made are mounted at one end of a double tube 6 feet long; each tube is rectangular in section and made of mahogany. At the opposite end are placed two 4-inch photo-visual Taylor lenses, each of 6 feet focal length and fixed permanently, the adjustment for focus being made at the slits, both of which are movable in and out of the tubes. In the optical axis of the collimator, but $16\frac{1}{2}$ inches to the south of the collimating objective, is placed a

lane mirror (Plate 9, fig. 3) held in a brass frame sup-
n three levelling screws. To preserve the surface when
rument is out of use a glass cover is placed over the
vithout disturbing any of the adjustments. Close to the
lens is a 6-inch Henry prism of 45° angle supported on a
base, also on levelling screws. The whole of this end is
in a blackened cardboard box, which is easily removed
cessary.

his way the light which falls on the primary slit is
l parallel by passing through the collimating lens; it
s on the plane mirror, is reflected at an angle on to the
of the prism, and after passing through the prism falls
bject-glass of the camera, the spectrum being formed in
e of the secondary slit. Thus the total deviation of the
r "K" is 180°.

void internal reflexions diaphragms are fixed both within
mator and camera tubes, and others are placed on the
d carrying the prism and reflector. The length of
n between F and K is 1·62 inch, so that the dis-
s sufficient if only the "H" and "K" lines of calcium
oyed. For work with other lines and for spot spectra
osed to replace the reflector by a grating, but up to the

adjustable steel plates fixed to its lower surface, is placed on the top of the first framework, the three balls running between the surfaces of the corresponding steel plates at the corners. To control the direction of motion of the upper framework a guide-bar is fixed on the lower one lying horizontally east and west. Against this the upper framework, which is fitted with two metal struts projecting downwards, is pressed against the guide-bar by two small levers, each having a roller on one arm running on the opposite side of the guide-bar and a small weight suspended on the other arm. These weights keep the metal projections in contact with the guide-bar. The motion of the upper framework is obtained by means of a steel band, one end of which is fixed to the west corner of this framework, while the other, after passing over a pulley fixed to the lower framework, carries a set of weights. To regulate this motion from east to west the upper framework is fitted with a metal plunger which projects downwards and fits into a slot forming part of a piston in the regulating oil cylinder firmly supported on the lower framework. This piston consists of a hollow cylinder open at one end and at the other two apertures, one comparatively large, with a valve to allow the entry only of the oil from the larger cylinder; and the other, variable in size, for the outlet of the oil from the piston during the movement of the framework. The open end of this cylindrical piston moves in and out of a closely fitting cylinder closed at the other end, so that the oil which is inclosed in them can only find its exit through the opening of variable aperture. A milled-headed micrometer screw and scale moving with the slot into which the plunger fits and attached to the piston varies the size of this oil outlet and allows perfect control of the escape of the oil from the inside of the piston to the cylinder without. For the purpose of setting the framework into its starting position, it is pushed towards the east by means of a long screw with attached handle working in a thread fixed in the same upright that carries the pulley. When the starting position has been reached, a small catch-lever fitted to one end of the piston falls into a slot on a projection inside the oil cylinder. This holds the framework in position, so that the setting screw is freed and can be wound back again. The actual starting of the motion is operated by a starting-handle attached to a long metal rod passing through the upper framework which raises the catch-lever out of its slot, and thus releases the piston. The framework thus being set free the weights pull it over in a westerly direction, and the piston pushes the oil from one cylinder to the other through the orifice the aperture of which is controlled by the adjusting micrometer screw. The maximum length of run which can be obtained by the motion is four inches.

With regard to the actual quality of the movement of the upper in relation to the lower framework, the motion is extremely smooth and far exceeds expectations. Even with such rapid movements as that of $2\frac{1}{2}$ inches in fifteen seconds scarcely any

uneven motion can be detected, even when the negative enlarged four diameters.

exposures, varying within wide limits, demanded by the g clearness and brightness of the image on the slit fairly accurate settings of the micrometer screw for any ar exposure. Experience soon showed that temperature nfluenced the rate of escape of the oil (sperm) which ermines the "run." A chart giving working details of uence of temperature became an immediate necessity. ary observations during adjustment gave some data ut in the form of a table aided in setting; the daily being added, the table gradually became of greater accuracy, and value. At present a setting of sufficient s by means of the chart is thus readily made.

table consists of a sheet divided into squares: in these al times of runs are entered, their position in the table etermined by a vertical scale of temperature and a al scale of micrometer readings. With a full sheet the ns for a run of any duration can be seen at once. As uare accumulates data, corresponding to a definite ture and micrometer reading, differences are noticed. re no greater than might be expected considering the y of timing a passage of the slit, the alteration of focal

Adjustment of Secondarg Slit on the "K" Line.

Up to the present time the setting of the central portion of the "K" line on the secondary slit has been accomplished by visual observation with the aid of a watchmaker's black eye, but it is hoped that a more satisfactory method will be available when the alterations and additions now in progress are completed. On bright days and with a high sun there is very little uncertainty about setting the line correctly, especially if a spot region be adjusted on the primary slit, so as to produce reversals on the "K" line at the secondary slit. On dull days the "K" region of the spectrum is very faint, and correct setting occupies much time. To control the correctness of the adjustment a photograph with the secondary slit wide open is often taken. This photograph also serves several useful purposes, for from it not only can the verticality of the secondary slit in relation to the spectrum lines be at once observed, but the position of the photographic plate in relation to the focal plane can be checked.

The Taking of the Photograph.

The adjustment of the secondary slit on the "K" reversal being satisfactory it is closed down by a micrometer screw to the desired width. Putting the primary slit in the meridian line through the siderostat and 12-inch lens, the solar image is brought by the siderostat slow motions into the meridian and centred on the slit. The focussing of the image on the slit is accomplished by placing a thin sheet of paper on the slit plate and moving the 12-inch lens until the solar limb, or spot, is quite sharp. In consequence of the brilliancy of the image the observation has to be made through tinted glass. The small shutter behind the primary slit is then closed. The loaded plate-holder is next slid into the carrier, and both secondary slit and carrier are as securely wrapped in velvet as is consistent with the necessary freedom of relative movement during the exposure. Pushing the whole upper framework, and with it the primary slit, to the east of the stationary solar image by the screw with attached handle, described above, the instrument is ready for a "run." The brightness of the image now determines the length of the exposure to be given.

The approximate temperature of the oil in the clepsydra is read by the attached thermometer. This enables the necessary micrometer screw-reading for the length of run to be obtained from the table of data compiled from previous observations.

The screw-plunger adjustment, facilitated by a conveniently placed electric pea lamp which lights the scale and a reading lens, both carried by the upper triangle, is readily made.

The slide of the plate-holder is now withdrawn under its velvet cover, and the signal for a favourable opportunity for

; waited for. This given, the final operations of opening ter of the primary slit and releasing the starting-handle ormed. The primary slit then moves uniformly westward, and glides through the stationary solar image, the "K" ord being continuously built up on the stationary photo-plate.

time of transit of the slit across the image is indexed as n." Closing the slit shutter and the slide of the plate-ompletes the essential instrumental operations.

btain a photograph of the prominences on the limb, a run" and the eclipse of the Sun's image by a zinc disc ed above) are necessary.

n these limb photographs are taken it is always attempted ce a "composite picture" by making an exposure for the the same plate. For the limb picture the disc must be ertically and close to, but not touching, the primary slit. is so chosen that it only allows an extremely small of the solar image at the limb to fall on the slit plate. t in position and the micrometer screw adjusted for the run," the procedure is the same as before.

naintain the image in position during the necessarily nger exposure, the siderostat slow motions are used when

Great care has therefore to be taken to allow the solar beam to fall on the lens for some minutes before taking a photograph and to adjust the focus on the primary slit immediately before making the exposure.

In the case of the limb photographs, when exposures of some minutes are required, this variation is a source of much trouble, and responsible for many unsatisfactory results.

Again the 4-inch Taylor objectives forming parts of the collimator and camera tubes have also been found to vary their focal lengths, though not to such a great extent. This has necessitated a frequent check being made on the position of the focal plane at the secondary slit.

Results.

Up to the present time the instrument has been employed for securing two classes of routine photographs.

(1) Disc photographs in "K" light.

(2) Composite disc and limb photographs also in "K" light.

These latter, though always striven for, were only obtained on the days of more continuous clear weather, and often several were obtained on days of special interest, such as when spots were near the limb.

Examples of these two kinds of pictures are shown in Plate 11, figs. 1 and 2, the former having been taken on 1904 September 20, and the latter on July 19 of the same year.

Dealing in the first instance with the photographs showing the "K" markings on the disc, the following general remarks, gathered from a preliminary examination of all the best plates taken between April and November, may be of interest.

The general feature of the surface of the disc is a universal "mottling" which seems to be made up of a fine mesh of small branching lines. They are not restricted to any zone, but are of the same character in both polar and equatorial regions. On clear days, with good definition and accurate setting of the line on the slit, this mottling becomes very obvious. More conspicuous than the above are the bright and more or less compact patches in middle and low latitudes. They have the appearance of being made up of the mottling, but exaggerated in size and intensity, and the compactness appears to be produced by the filling up of the interspaces with bright patches; in fact in these regions there is a tendency to form a more intense nucleus with radiating arms, and the resemblance to foam traces in deep water disturbed from below is very striking. Plate 12 gives an idea of this apparent building up of a flocculus in the manner above described. It will be seen that there are very frequently long streaky bright portions springing from a central nucleus and having subsidiary ramifications. A three-legged formation with central brightening is a very common type of structure.

he majority of cases flocculi exist where no spot is but spots never appear unless surrounded by these clouds. They resemble and possibly are identical with at least) the faculæ, and in consequence are restricted to s of the latter.

n a number of groups appear on the disc together the nent into equatorial belts is very pronounced. Their tion in longitude is intermittent more than continuous te 11), but this may not be the case at other phases of spot cycle.

n regard to the relation of spots to these calcium clouds iced that the former appear more generally near the head ecede the apparently trailing masses of the latter with o the solar rotation. Typical examples of this relation- given in Plate 13. There seems to be little doubt that tion of spots in flocculi is not due to chance, but that there physical reason dominating the cause and effect in their positions. This is a point that requires investigation veral complete series of photographs, extending over semi- periods of the Sun, have been secured. Such photo- will probably throw much light on the various phases in history of a spot group, and classifications, such as that ard by Father Cortie, S.J.,* may possibly be extended

two photographs, about one hour, a startling change occurred to the largest prominence; and not only has its height been considerably increased, but its form has altered. The material forming the prominence seems to have been ejected from the chromosphere and then to have met a strong current moving polewards (*i.e.* from left to right in the figure), which has thrown this material in that direction. The change of height from 50,000 to 60,000 miles in this interval gives an approximate rate of movement away from the chromosphere of about two and a half miles per second.

It will be noticed that the other large prominence (No. 5) in the same figure has during that interval nearly disappeared in spite of its exceeding intensity in the first photograph. In the second case (Plate 14, fig. 2) we have an enormous prominence in the spot zone that was secured on 1904 July 19, the upper and the lower photographs having been taken at $11^h\ 44^m$ A.M. and $3^h\ 52^m$ P.M. G.M.T. respectively. This prominence was situated in the S.E. quadrant, the higher portions being directed towards the equator. The approximate greatest heights and lengths on the two photographs were as follows:

h m	Length.	Height.
11 44	192,000	55,000
3 52	216,000	60,000

[To show the complete record both on the limb and disc at the first of these times, see Plate 11, fig. 2.]

Although the interval here is over four hours, there is not such a considerable alteration in form as that recorded in Plate 14, fig. 1.

In many of the remarks relating to the disc and limb pictures it must not be forgotten that they only apply to the photographs secured in 1904. At any other time, such as a sun-spot minimum or maximum, the solar activity is different, and therefore changes of another kind may be apparent. Thus, for instance, the mottling on the disc may be more, or it may be less, pronounced than it was in 1904, while the flocculi may be more connected in longitude than was the case in 1904, when they were intermittently distributed in longitude.

In conclusion, I should like to express my obligations to the Director of the Observatory, Sir Norman Lockyer, for allowing me to prepare the present paper for communication to the Society. Messrs. W. Moss and T. F. Connolly assisted me in taking the photographs, and Mr. J. P. Wilkie in preparing the plates.

Description of the Plates.

PLATE 9.

[redacted]th ends of the collimator and camera tubes showing the
[redacted] holder carrier and metal disc in position for a limb photo-

[redacted] of the curved secondary slit showing the screw adjust-

[redacted]outh ends of the collimator and camera showing the
[redacted] reflector and prism (p. 478).
[redacted] H" and "K" portion of the solar spectrum (enlarged
[redacted]the curvature of the lines. The sun-spot absorption is also
[redacted]versals of the "H" and "K" lines near the spot region

PLATE 10.

[redacted] the spectroheliograph (p. 478).

PLATE 11.

[redacted]disc in "K" light as photographed on 1904 September 20
[redacted].T. Exposure 73^s. Enlarged about $1\frac{1}{3}$ time (p. 483).
[redacted]site photographs of Sun's disc and limb in "K" light as
[redacted]904 July 19 at $11^h\ 45^m$ A.M. G.M.T. Exposure for disc 18^s,
[redacted] Enlarged about $1\frac{1}{3}$ time (p. 483).

PLATE 12.

[redacted] to illustrate how these large "K" clouds are built up by
[redacted]f the smaller but somewhat intense "mottling." The dates
[redacted]ide correspond to the days on which the photographs were
[redacted]imb of the Sun is towards the right. Enlarged about four

[redacted]

K. H.

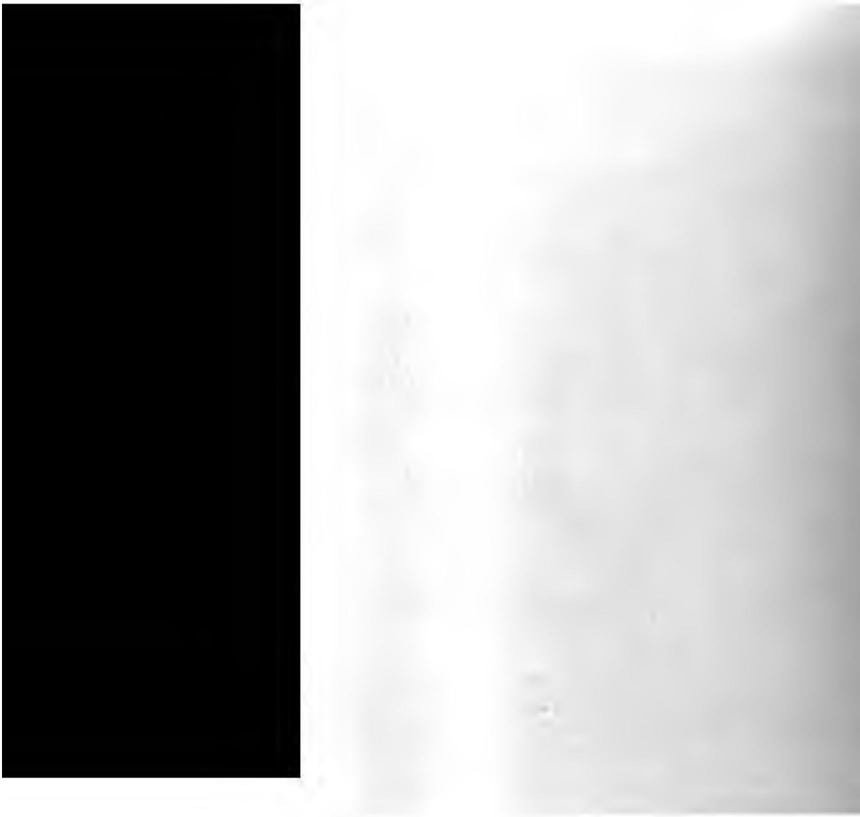
FIG. 4.

FIG. 1.

FIG. 2.

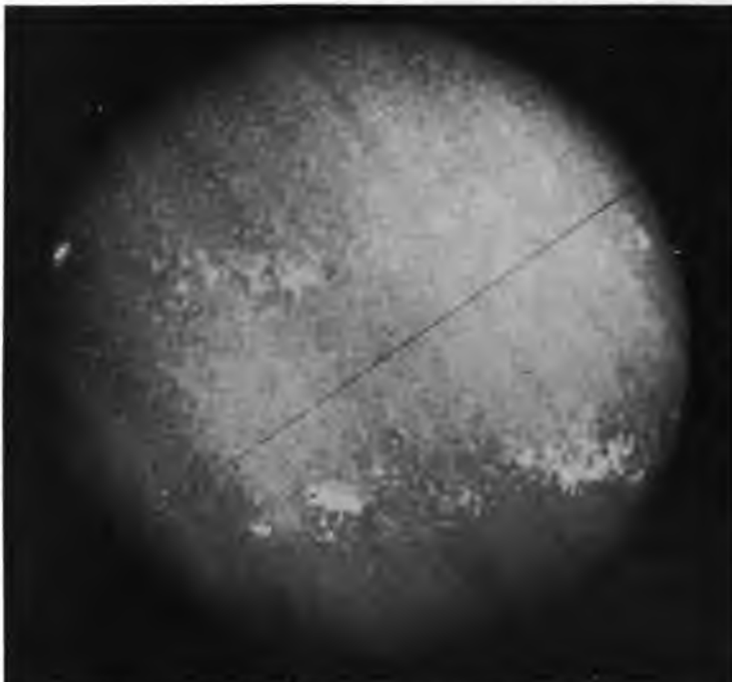
FIG. 3.

GENERAL VIEW OF SPECTROHELIOGRAPH.



N.

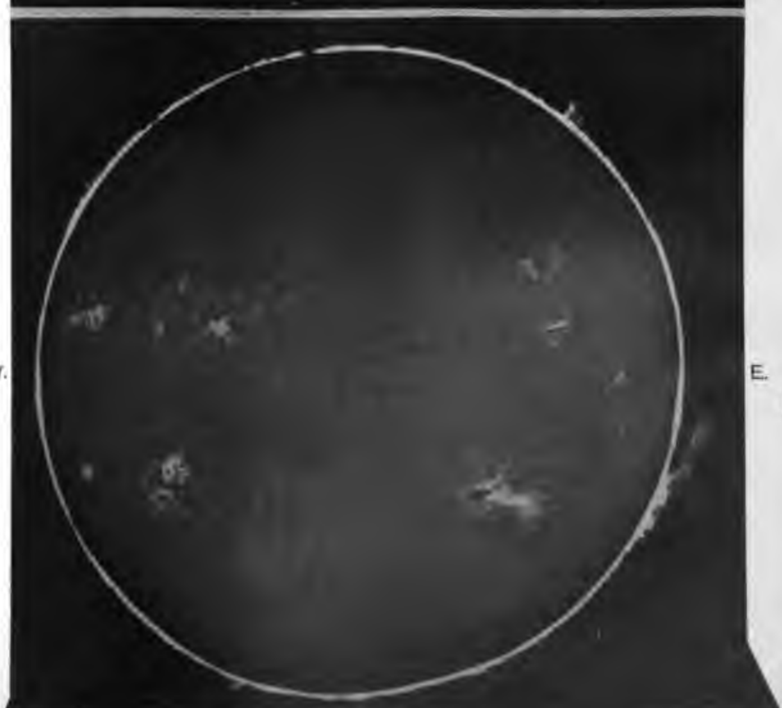
W.



E.

Fi

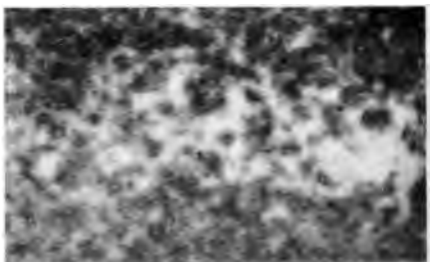
W.



E.

Fi

[redacted]

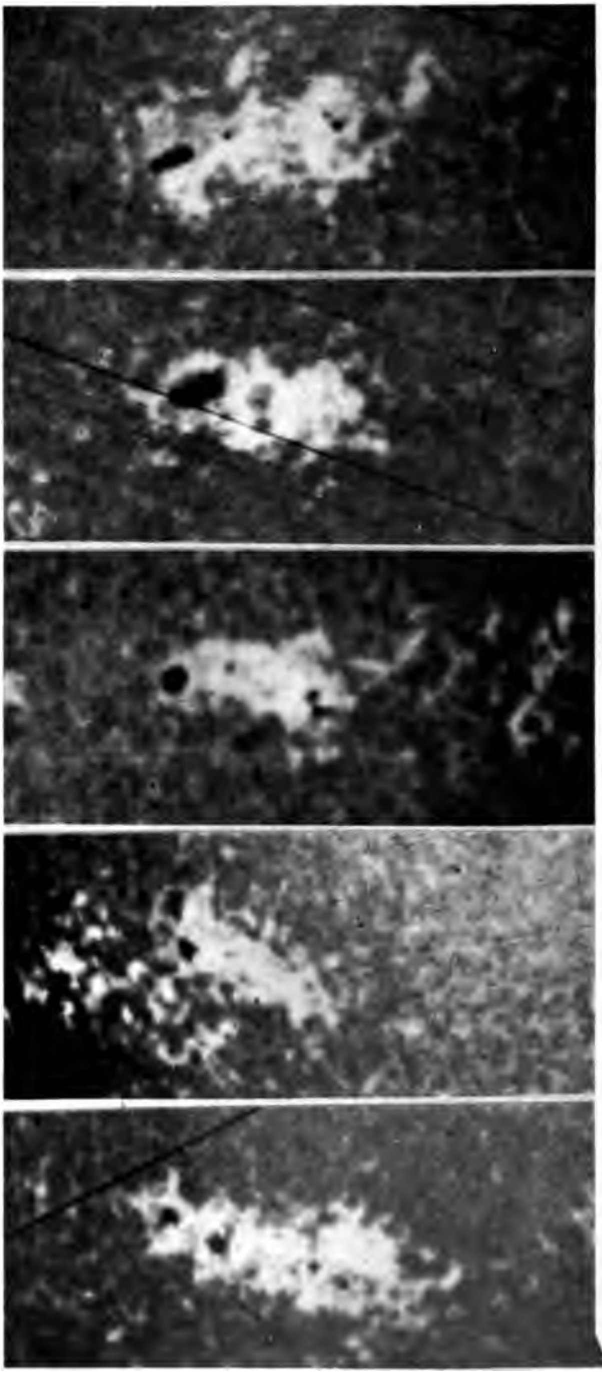


1904.
May 23.

Aug. 2.

Sept. 26.

Sept. 26



1904.
April 27.

April 27.

July 14.

Aug. 2.

Aug. 29

WEST. EAST.

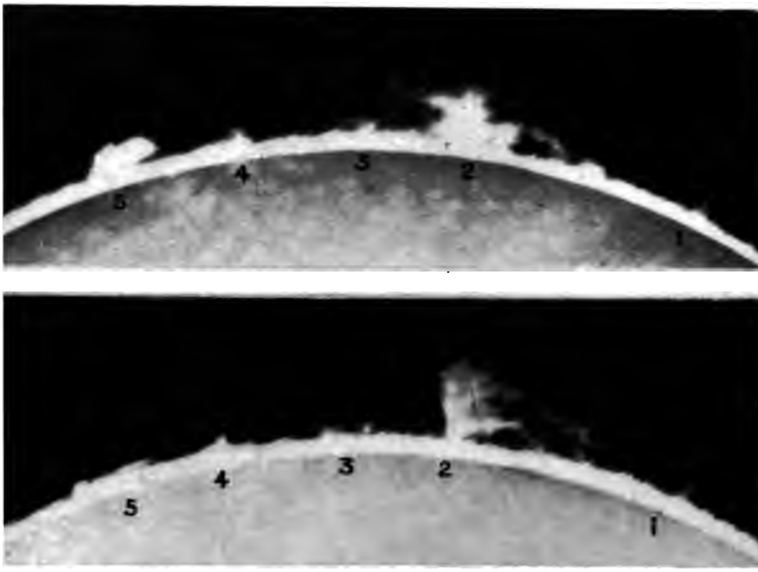


FIG. 1.

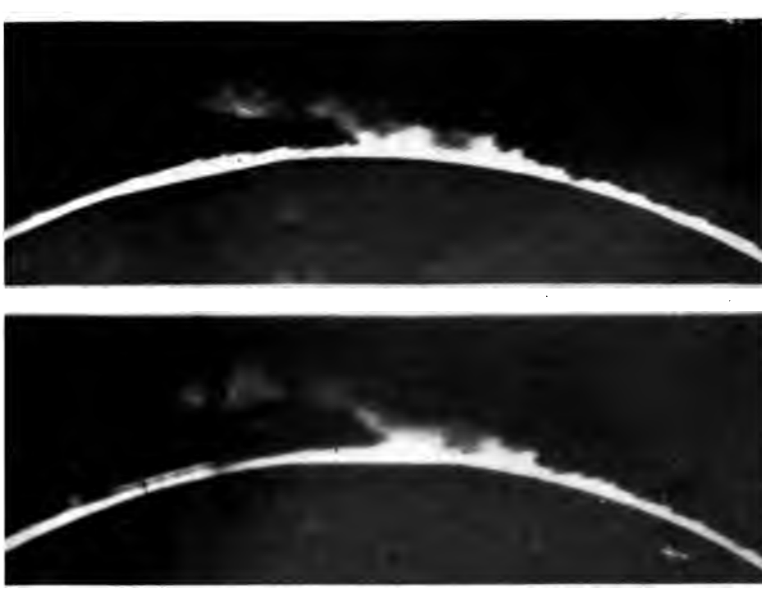


FIG. 2.

Notes on the Cœlostat and Siderostat. By H. C. Plummer, M.A.

1. At the present time the desirability of using telescopes of exceedingly great focal length is urgently felt. There is no insuperable difficulty in making reflectors or lenses with focal lengths of a hundred feet or more, but it is practically impossible to mount instruments of this size in such a way that they can be directed to any part of the sky and made to follow the diurnal motion of the stars. They must be placed in stationary positions, and the simplest construction is possible when the telescope is horizontal. In order that any part of the sky may be observed in the telescope, it is necessary to place a plane mirror in front of the reflector or object-glass. The mirror may be mounted in such a way that as a particular star describes its diurnal path, its image remains fixed in the field of the telescope. If this is the case the motion of the mirror must be of a simple and definite geometrical type (cf. *Monthly Notices*, vol. lxi. p. 459) which may be called siderostatic, although the motion of the siderostat may be produced by many different forms of mechanism. The use of a siderostat, notwithstanding the advantages which it offers, is not free from objection. In spite of the ingenuity which has been devoted to several forms of construction it has been generally felt that the mechanical design of the instrument leaves much to be desired. The largest and most elaborate siderostat yet made was that shown at the Paris Exhibition, 1900; but unfortunately no information seems to have been published on which a reliable judgment of its performance can be based. Dr. Johnstone Stoney (*Monthly Notices*, vol. lvi. p. 452) has suggested a way in which the chief mechanical defect of the older forms may be avoided, but I am not aware that the suggestion has been embodied in an instrument of sufficient size to test its practical value.

2. In addition to the admitted defects of the siderostat itself, a further difficulty arises from the variable rotation of the field. For photographic purposes the rotation may be compensated by one of several devices which have been suggested for turning the plate. But however complete the mechanical arrangements there will be the same ultimate need for hand-control as is found with the equatorial, owing to inequalities of driving and the effect of refraction. In this case it is necessary to watch not one, but two stars in order to control the orientation of the field. It will probably be found that two eyepieces and two observers are required. Hence the advantage of using a cœlostat—which is that limiting form of siderostat which gives a field of constant orientation—is very evident. Moreover the uniform rotation of the mirror about a fixed axis requires the simplest possible mechanism. But on the other hand a fixed telescope in conjunction with a cœlostat commands only one definite declination in the sky, and other declinations must be reached by moving

scope either actually or virtually, the latter being the
n the rays reflected by the cœlostat are deflected to the
escope by a subsidiary plane mirror. The Snow tele-
the Yerkes Observatory is an example of the use of a
nirror in this way. The conditions on which the efficient
of the combination depends deserve some consideration,
investigation of them seems to have been published.
examining this question, however, it is intended to
the possibilities presented by a single mirror which is
l in a simple way—namely, such as to allow independent
s about two orthogonal axes.
et us suppose in the first place that the mirror is
ally mounted, the normal to the mirror corresponding
kis of the telescope; so that the normal can be adjusted
desired N.P.D. and driven in right ascension by clock-
The instrument becomes an ordinary cœlostat when the
is 90°, and the velocity in R.A., N, is half the actual

the mirror. Then P′ rotates uniformly round P at a distance 2ν with the angular velocity N, carrying with it a picture of the sky which rotates uniformly with respect to PP′ with the velocity $n-N$.

If $PS = P'S' = \Delta$, the circle whose centre is P′ and radius Δ touches the circle whose centre is P and radius $2\nu-\Delta$. Let M be the point of contact. Owing to the rotation of M round P′, the linear velocity of M on the sphere has a component proportional to $(n-N)\sin\Delta$ in one direction, and owing to the rotation of PP′ about P, it has a component proportional to $N\sin(2\nu-\Delta)$ in the opposite direction. Hence if

$$(n-N)\sin\Delta = N\sin(2\nu-\Delta)$$

or

$$\frac{N}{n} = \frac{\sin\Delta}{2\sin\nu\cos(\nu-\Delta)} \quad \ldots \quad \ldots \quad (1)$$

the point M is instantaneously at rest. It follows that the motion of the field may be represented as due to the rolling of the spherical cap whose centre is P′ and radius Δ on the rim of the spherical cap whose centre is P and radius $2\nu-\Delta$. The reflected ray from every star therefore traces a spherical roulette. The motion can also be ascribed to the rolling of one right circular cone on another whose axis is the polar axis.

4. In the case of the properly adjusted cœlostat $\nu = 90°$ and $n = 2N$, so that equation (1) is satisfied identically. The moving circle rolls on itself and the field is permanently stationary, so that a telescope pointed at the mirror will always see the same stars. If the rate of driving is $\frac{1}{2}n$ as for the cœlostat, but the N.P.D. of the normal to the mirror, ν, is not 90°, the rolling and fixed circles are equal but not coincident, and the radius of each is ν. If (ρ, θ) are the polar coordinates of S′, the sides of the triangle S′PP′ are ρ, 2ν, and Δ; and if the angle at P′ is χ, the angle at P is $\chi-\theta$. Hence by eliminating the angle at S′ from two of Delambre's analogies which involve the difference of the angles at P and P′, the polar equation of the locus of S′ on the sphere is easily found to be

$$\sin^2\rho + \sin^2\Delta - 2\sin\Delta\sin\rho\cos\theta = \cot^2\nu\,(\cos\rho - \cos\Delta)^2$$

The orthogonal projection of this curve on the equatorial plane can be found in polar coordinates by putting

$$r\cos\phi = \sin\rho\cos\theta - \sin\Delta,\quad r\sin\phi = \sin\rho\sin\theta$$

The result of making this substitution is to obtain the ordinary equation of a *limaçon* referred to its pole, which is clearly the projection of the point obtained when $\nu = \frac{1}{2}\pi$, *i.e.* with a cœlostat in perfect adjustment. This theorem is due to Professor Turner (*Monthly Notices*, lvi. p. 419).

5. Since in the general case the motion of the sky as viewed

otating mirror is that which arises from the rolling of one
a another, it appears that the mirror introduces a com-
which is absent in the simple rotation of the sky as
directly. But the fact that a star on the instrumental
n can be reflected in a chosen direction and by a suitable
driving kept stationary even for an instant suggests that
t without interest to examine the state of things when
is followed to some distance from the meridian. By a
djustment of the rate of driving, provided the clock is
of a considerable range in this respect, the reflexion of
can be maintained on the meridian, and its motion in
ne may be compensated by moving the plate-holder.
ct is comparable with that which would be caused by an
ted refraction. There is also a rotation of the field, but
ld equally be the case if a siderostat were used. Con-
y if the motion in declination of the reflected ray could
n not to exceed a manageable amount, the method would
o be practicable, and the extremely simple mounting of
or gives the question some practical importance.

The corresponding clock-rate is obtained by differentiating the first equation between h and H. This gives

$$\frac{N}{n}=\frac{dH}{dh}=\frac{2\sin^2\nu\sin^2 H\sin(h-H)+\sin H\cos h}{2\sin^2\nu\sin^2 H\sin(h-H)+\cos H\sin h}$$

or

$$(n+N)/(n-N)=4\sin^2\nu\sin^2 H+\sin(h+H)/\sin(h-H)\ \ldots\ (3)$$

The displacement of the point S′ on the meridian, reckoned from the position corresponding to S on the meridian, is $\rho+\Delta-2\nu$. Now one of Napier's analogies gives

$$\tan\tfrac{1}{2}(\rho+\Delta)=\cos\tfrac{1}{2}(h-2H)\sec\tfrac{1}{2}h\tan\nu\ \ldots\ (4)$$

which leads to

$$\sin\tfrac{1}{2}(\rho+\Delta-2\nu)/\sin\tfrac{1}{2}(\rho+\Delta+2\nu)=\tan\tfrac{1}{2}H\tan\tfrac{1}{2}(h-H)\ \ldots\ (5)$$

This shows that the displacement may be very small. The angle through which the field has turned since S passed the meridian is QS′P′, which may be denoted by θ. Then clearly

$$\sin\theta=\sin 2\nu\sin H/\sin\Delta\ \ldots\ \ldots\ (6)$$

and

$$\cos\theta\,.\,\frac{d\theta}{dh}=\frac{\sin 2\nu\cos H}{\sin\Delta}\,.\,\frac{N}{n}\ \ldots\ \ldots\ (7)$$

The formulæ of this paragraph are all exact and suffice to determine with accuracy the relations between the clock-rate and the diurnal motion of the stars, the displacement of the reflected image in the plane of the instrumental meridian and the variable rotation of the field.

7. For our present purpose, however, which is simply to inquire whether the instrument is practicable for comparatively short exposures near the meridian, approximate formulæ are sufficient. The form of the equations shows that the neglect of powers of h higher than the first will not materially affect the results to be expected. Thus from (2)

$$K=2H\sin^2\nu$$
$$h-K=H\cot\Delta\sin 2\nu$$

whence

$$H/h=\sin\Delta/2\sin\nu\cos(\nu-\Delta)\ \ldots\ \ldots\ (8)$$

By (3) this is also the value of N/n, a result already found in equation (1). The displacement in the plane of the meridian is given by (5) in the form

$$\rho+\Delta-2\nu=\tfrac{1}{2}H(h-H)\sin\tfrac{1}{2}(\rho+\Delta+2\nu)$$

comes, when ρ is given its initial value on the right-hand

$$\Delta-2\nu = h^2 \sin\Delta \sin(2\nu-\Delta)/4 \tan\nu \cos^2(\nu-\Delta) \quad \ldots (9)$$

of rotation of the field, as given by (7), is

$$\frac{d\theta}{dh} = \frac{\cos\nu}{\cos(\nu-\Delta)} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

ation is relative to the fixed meridian PQ, while that § 3 is relative to the moving meridian PN, and has a value, namely, $n-N$.

ome numerical results can now be given. In the case or the purpose of illustration the latitude is 50° and the is placed in a horizontal position in the local meridian. $= 130°$ initially. The column headed R_1 gives the ate of the mirror in R.A. compared with the correspond- -rate of an equatorial. The column headed R_2 contains al rotation of the field, expressed as a fraction of one rotation in a day. Under the heading D is given the nent of the image of the guiding star in the first minute sing the meridian.

is obtained by multiplying the numbers in the last column by the square of the number of minutes in the hour-angle. The inferences to be drawn from the table are clearly uncertain in the absence of actual experiment. But it would appear at least feasible, with an instrument of the kind considered, to obtain photographs with moderate exposures (up to 20 minutes say) of a belt of the sky extending perhaps 30° south of the zenith.

9. Very steady driving may be expected from a mirror with simple equatorial mounting, and it would probably be best to adjust the clock-rate at the beginning of the exposure of the plate and to apply the adjustment afterwards necessary to the plate-carrier by means of two rectangular slides. By moving the normal to the mirror in N.P.D. the siderostat condition might be partially or completely satisfied, and it would be necessary to apply merely a rotation to the plate. This would complicate the mounting of the mirror, and would probably interfere with the steadiness of the driving. Yet it is a matter of interest to examine the nature of the motions which must be communicated to a mirror capable of rotating about two orthogonal axes in order that it may satisfy the siderostat condition. This problem differs from the one previously considered merely in the fact that ρ is constant and ν variable, instead of the converse. The triangle PS′P′ (fig. 2) has for its angles H, $\pi-\theta$ and $h-\mathrm{H}$, and for its sides Δ, 2ν and ρ. Hence three of Napier's analogies give immediately

$$\tan\tfrac{1}{2}\theta=\frac{\cos\frac{1}{2}(\rho+\Delta)}{\cos\frac{1}{2}(\rho-\Delta)}\tan\tfrac{1}{2}h \qquad \ldots \quad \ldots \quad \ldots \quad (11)$$

$$\tan\nu\cos\tfrac{1}{2}(h-2\mathrm{H})=\cos\tfrac{1}{2}h\tan\tfrac{1}{2}(\rho+\Delta)$$

$$\tan\nu\sin\tfrac{1}{2}(h-2\mathrm{H})=\sin\tfrac{1}{2}h\tan\tfrac{1}{2}(\rho-\Delta)$$

The first of these gives the law of rotation of the field, discussed by Cornu. The other two equations lead to

$$\left.\begin{aligned}\tan\nu\sin\mathrm{H}&=\frac{\sin\Delta\sin h}{\cos\rho+\cos\Delta}\\ \tan\nu\cos\mathrm{H}&=\frac{\sin\rho+\sin\Delta\cos h}{\cos\rho+\cos\Delta}\end{aligned}\right\} \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

or

$$\left.\begin{aligned}\tan\nu&=\frac{(\sin^2\rho+\sin^2\Delta+2\sin\rho\sin\Delta\cos h)^{\frac{1}{2}}}{\cos\rho+\cos\Delta}\\ \tan\mathrm{H}&=\frac{\sin\Delta\sin h}{\sin\rho+\sin\Delta\cos h}\end{aligned}\right\} \quad \ldots \quad (13)$$

which express the laws of motion about the two axes.

10. From these may be deduced the character of the motion about two axes, of which one is fixed in the instrumental meridian plane and inclined to the polar axis at an angle α. Let O represent (fig. 2) the direction of the fixed axis, and let

ν' and QON $=$ H$'$. The form of equations (12), which e "standard coordinates" of the direction of the normal to ror, suggests a transformation in rectangular coordinates. polar system

$$\sin \Delta \sin h, \quad y = \sin \rho + \sin \Delta \cos h, \quad z = \cos \rho + \cos \Delta$$

xes are turned through an angle α about the axis of x,

$$' = x, \quad y' = y \cos \alpha - z \sin \alpha, \quad z' = y \sin \alpha + z \cos \alpha$$

new system, as in the old,

$$\tan \nu' \sin \mathrm{H}' = x'/z', \quad \tan \nu' \cos \mathrm{H}' = y'/z'$$

the motion of the mirror, with respect to the new axes, is y

$$\left.\begin{aligned} \text{in } \mathrm{H}' &= \frac{\sin \Delta \sin h}{\cos(\rho-\alpha) + \cos \alpha \cos \Delta + \sin \alpha \sin \Delta \cos h} \\ \text{os } \mathrm{H}' &= \frac{\sin(\rho-\alpha) - \sin \alpha \cos \Delta + \cos \alpha \sin \Delta \cos h}{\cos(\rho-\alpha) + \cos \alpha \cos \Delta + \sin \alpha \sin \Delta \cos h} \end{aligned}\right\} \quad (14)$$

From these results a number of particular cases can be

It follows that when the fixed axis has the position indicated by this equation, the variation of ν' depends on the fourth power of the time, and is at first very slow. When the example of § 8, in which $\rho = 130°$, is examined, equation (15) gives the following numerical results:

Δ	a	Δ	a	Δ	a
10°	43° 5′	50°	0° 0′	90°	12° 44′ S.P.
20	25 58	60	4 22 S.P.	100	14 40 „
30	14 4	70	7 45 „	110	16 21 „
40	5 51	80	10 28 „	120	17 51 „

12. The advantage of the form of mounting which has been examined lies in the stability which it renders possible, a feature in regard to which the ordinary form of siderostat is liable to grave suspicion. It is not impossible that an entirely satisfactory method may be available for producing the motions defined by equations (13). It is easy to devise a linkage which contains the solution of the problem, and though link-motions are not free from objection, any method which is based on a new principle, as this appears to be, possesses a certain interest. Let O and C (fig. 3)

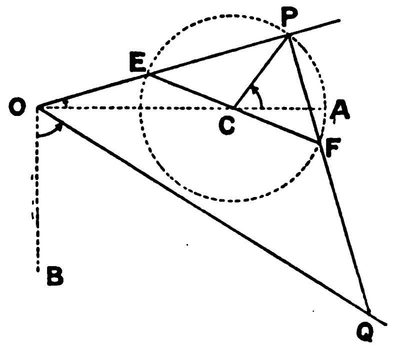


FIG. 3.

be two points fixed at a distance apart equal to sin ρ. Let CP, CE and CF be each equal to sin Δ on the same scale and PQ to $\cos\rho + \cos\Delta$. The lines OP, PQ, and OQ represent slotted bars, so that the points P and E are free to move along OP, F along PQ, and Q along OQ. Then if CP rotates uniformly in twenty-four hours so that the angle ACP is h, A lying on OC produced, we have

$$\tan \text{AOP} = \sin\Delta \sin h/(\sin\rho + \sin\Delta\cos h)$$

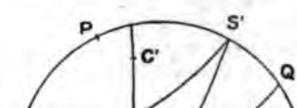
$$\tan \text{OQP} = \text{OP}/\text{PQ}$$

$$= (\sin^2\rho + \sin^2\Delta + 2\sin\rho\sin\Delta\cos h)^{\frac{1}{2}}/(\cos\rho + \cos\Delta)$$

for OPQ is a right angle. Hence AOP is the angle H and OQP is the angle ν. If OB is perpendicular to OA, the angle BOQ is

› ν+H. It follows that if the point O is on the polar
l the plane of the linkage is perpendicular to this axis, a
f which OP is a radius rigidly connected with the mirror
nmunicate the required motion in R.A., while a second
of which OQ is a radius, if suitably geared round the
› a wheel on the moving axis, will communicate the re-
motion in N.P.D. This constitutes a solution of the
at problem. The adjustment for different declinations
; the ratios of OC, CP and PQ. Probably the most con-
method would be to keep CP constant and to vary OC
.

The use of a cœlostat in conjunction with a second mirror,
leflects the rays from the cœlostat into a permanently
escope, has been mentioned in § 2, and the possibilities of
angement may now be considered. The position of the
e is supposed to be horizontal, and can be specified by the



reflected in the direction of the point are Δ and h, and if the hour-angle of the normal to the cœlostat is H, then

$$\Delta' = \pi - \Delta, \qquad h' = 2\mathrm{H} - h$$

Each point on the axis of the telescope corresponds to a definite declination, and the effect of turning the cœlostat in any manner is to bring different hour-angles into view.

The relations between the position of any point on the sphere and of its reflexion in the cœlostat are equivalent to two steps which it is convenient to consider as made successively. These consist in passing, first, to the image of the point in the plane of the equator; and, secondly, in passing to the image of this image in the plane of the meridian which contains the normal to the cœlostat. Now let N′WS′ be the image of the horizon in the equatorial plane, and let T′C′R′ be the image of the semicircle TCR. Then clearly T′C′R′ is also a semicircle with its extremities on N′WS′, and inclined to N′WS′ at the same angle as TCR to NWS. It lies wholly on one side of the image of the horizon, and its position decides the range of declination which the telescope can command. Then by suitably choosing the position of the normal to the cœlostat any point in T′C′R′ can be brought, subject to certain limitations which must be examined, to any desired hour-angle in the sky.

14. The limitations referred to are imposed by the maximum angle of incidence on the cœlostat which can in practice be allowed. This angle cannot exceed 60°, in which case the effective aperture of the cœlostat is reduced by one half, and ought, if possible, to be less than 45°. Denoting the angle of incidence by i and its limiting value by I, we have

$$\cos i = \sin \Delta \cos \tfrac{1}{2}(h' - h) \not< \cos \mathrm{I}$$

and so we obtain for the two values of I the following limiting values of $h' \sim h$:

I = 60°.

$\Delta =$	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
$h' \sim h =$	$0^{h}\cdot0$	$5^{h}\cdot2$	$6^{h}\cdot6$	$7^{h}\cdot3$	$7^{h}\cdot7$	$7^{h}\cdot9$	$8^{h}\cdot0$	$7^{h}\cdot9$	$7^{h}\cdot7$	$7^{h}\cdot3$

I = 45°.

$\Delta =$	45°	50°	60°	70°	80°	90°	100°	110°	120°
$h' \sim h =$	$0^{h}\cdot0$	$3^{h}\cdot0$	$4^{h}\cdot7$	$5^{h}\cdot5$	$5^{h}\cdot9$	$6^{h}\cdot0$	$5^{h}\cdot9$	$5^{h}\cdot5$	$4^{h}\cdot7$

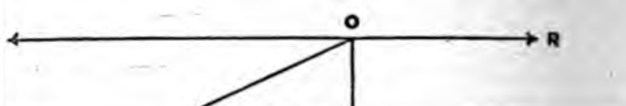
By the nature of the case the sky in the neighbourhood of the pole to a distance equal to $\frac{1}{2}\pi - \mathrm{I}$ cannot be brought within the field of the telescope.

15. The circumstances of the reflexion at the surface of the subsidiary mirror need explanation. The point O (fig. 5) is the centre of the cœlostat and the centre of the sphere represented in fig. 4. The axis of the telescope, which is pointed in a direc-

allel to OT, is CM, C being the foot of the perpendicular and M the position of the mirror. Let $OC = d$, , and $TOM = a$, so that

$$x = d \cot a$$

rmal to the mirror MV is in the plane TOC, and the MC is $\frac{1}{2}a$. The axis about which the mirror must be of turning is normal to the plane TOC and so is fixed in n. The angle of incidence on the mirror being $\frac{1}{2}a$, we $> 2I'$, where I' is the greatest angle of incidence allowed. for which $a = 0$ cannot be brought into the field of the e; and if an upper limit is assigned to x, the distance of ror from C, there is a corresponding lower limit to a.
omplete the investigation of the circumstances on which stment of the mirror depends, it is necessary to find the s between a, Δ' and h' in terms of the data which express



from N through W) of the point C with Δ_0', h_0', the N.P.D. and hour-angle of the same point, may also be useful. They are

$$\left.\begin{aligned} \cos Z &= \cos\Delta_0' \sin\phi + \sin\Delta_0' \cos\phi \cos h_0' \\ \cot A \sin h_0' &= \cot\Delta_0' \cos\phi - \sin\phi \cos h_0' \end{aligned}\right\} \quad \ldots \quad (17)$$

16. The principles discussed above enable us to examine the nature and relative advantages of different arrangements which are possible. In choosing a suitable disposition of the instruments there are three main factors to be considered: namely, (*a*) the effective range of declination within reach; (*b*) the hour-angle of the part of the sky under observation; and (*c*) the angle of incidence at the cœlostat. The two latter are, as we have seen, closely related, while the first factor depends entirely on the position of the arc T′C′ (fig. 4) in the sky. A few typical arrangements will now be briefly examined.

(1) T′ coincides with S′, and C′ is taken on S′S. From the corresponding position of TC it is clear that this means that the telescope is pointed due south, and its axis passes directly *over* the cœlostat, for C coincides with the zenith. The whole of the southern meridian is observed under the best possible conditions to a distance from the pole equal to the latitude, the limits of N.P.D. being ϕ and $\pi - \phi$. Except in very high latitudes this position is always suitable for solar work, and is in fact the one adopted for the Snow telescope.* Its maximum efficiency requires a moderately low latitude. In latitude 40°, for example, the meridian can be observed up to and beyond the zenith, and the only part of the sky which lies out of reach is the vicinity of the pole, for which the cœlostat is by its nature inadequate.

(2) T′ coincides with S′ and C′ is taken on S′P. The telescope is pointed due south and its axis passes *underneath* the cœlostat. This position supplements the former and brings under observation that part of the meridian whose limits of N.P.D. are ϕ and $\frac{1}{2}\pi - \mathrm{I}$.

(3) Still keeping the telescope pointed south, we may place its axis on a level with and west of the cœlostat, so that C′ comes to W. For the arc S′W the limits of N.P.D. are ϕ and $\frac{1}{2}\pi$. Without making the angle of incidence at the cœlostat excessive, the available part of the sky can be observed on or near the meridian. But this case is clearly inferior to (1), and it is fairly evident that with the telescope pointed south it is impossible to place the axis so as to obtain any advantage by combining parts of the ranges in N.P.D. covered by cases (1) and (2).

(4) T′ coincides with N′ and C′ lies on N′P. The telescope is pointed due north, and its axis passes *underneath* the cœlostat. This case at first sight offers the greatest advantage with regard to the range in N.P.D., for the arc extends over N′P and corresponds to the whole of the visible sky. But if we apply the

* This is only approximately true as the telescope is at present installed on Mount Wilson. See *Astrophysical Journal*, 1905 March, p. 163.

ound in § 14 we shall find that the effective range is
urtailed; and even so it is necessary to have a large angle
nce at the cœlostat, and to work at a quite impracticable
le. This case presents no advantage.
'he telescope is pointed due west. This position may
mended by local considerations as to available space, and
st be taken into account as well as the factors already
ed. In this case T′ coincides with W and C′ lies on the
and must be placed either on QP or on QS, so that the
sky is entirely above or below the equator. (*a*) If
is the best position for C′; and if this is adopted, C coin-
th S′, and the perpendicular from the cœlostat to the
he mirror is inclined southward at an angle $2\phi-\frac{1}{2}\pi$ to
ard vertical, the range in N.P.D. being from $\frac{1}{2}\pi$ to $\pi-\phi$.
s would naturally be the case in a moderately high
north declinations are required, C′ may be taken at a
$\frac{1}{2}\pi-I$ from P, so as to obtain the greatest range of
ion possible at the most favourable hour-angle. The
icular from the cœlostat to the axis of the mirror is
southward at an angle $\phi+I$ to the upward vertical.
ge covered in N.P.D. extends from $\frac{1}{2}\pi-I$ to $\frac{1}{2}\pi$. This
herefore superior to (3) at places where the co-latitude is
the greatest angle of incidence at the cœlostat which is

[redacted]

voided by the use of a second mirror fixed so as to deflect the ays from the heliostat in any desired direction. In this way a olar heliostat can be used in conjunction with either a horizontal r a vertical telescope.

19. The contents of this paper may be summarised thus :

(1) §§ 1 and 2 are introductory.

(2) §§ 3 and 4 deal with the geometry of a mirror caused to otate with uniform angular velocity about the polar axis, which s inclined at a constant angle to the plane of the mirror.

(3) §§ 5–8 contain a discussion of the properties of a mirror imilarly mounted, but rotated with such a (variable) velocity hat the image of a particular star is maintained on the instrunental meridian.

(4) §§ 9–11 deal with the motion of a siderostat considered s a mirror capable of rotation about any two orthogonal axes, ne of which is fixed in the plane of the instrumental meridian.

(5) § 12 describes a linkage which is capable of producing he motions required by a siderostat which is mounted equaorially.

(6) §§ 13–15 deal with the geometrical conditions on which he efficient use of a second mirror in conjunction with a œlostat depends when the telescope is fixed in a horizontal osition, and with the necessary adjustment in the position of he mirror.

(7) § 16 is devoted to an examination of certain typical ositions of the telescope.

(8) §§ 17 and 18 refer to the use of a cœlostat with a telecope pointed to the zenith and to the possible advantage of polar heliostat combined with a fixed mirror.

University Observatory, Oxford :
1905 *March* 8.

The Optical Sine-condition. By A. E. Conrady.

The remarkable theorem which forms the subject of this aper was brought to the notice of astronomers in general by the tipulations agreed upon at the Paris Congress for standardising he construction of the astrographic telescopes ; for, on the ecommendation of Dr. Steinheil, one of the German delegates, it vas laid down that the objectives must fulfil the sine-condition, o as to insure the formation of symmetrical images in the outer art of the relatively large field that had to be covered.

A short history of this theorem and a simple proof of it may herefore be acceptable.

Owing to its close association with the complicated defect nown to opticians as "coma," it is a matter of course that this

n is found approximately fulfilled by all reasonably
ıl lens-systems, even those made by purely cut-and-try
.

in the case of the famous object glasses made by Fraun-
the early part of the last century, more particularly in
h discussed objective of the Königsberg heliometer, the
ıt of the condition is such an exceedingly close one as to
orce one to assume that it was arrived at deliberately by
tion. But the latter was most probably an elaborate
ıetrical one for an oblique pencil of rays, which, thanks
sine-condition, modern computers can generally do

first theoretical paper which gave something nearly akin
ıodern form of the sine-condition was a classical one by v.
in which the elementary dioptric theory was extended so
lude all terms of the third order, the result being that
l showed that a lens-system must fulfil five separate
ns in order to give a sharp and plane image of an ex-
bject ; the second of these five conditions corresponds to
ern sine-condition, but it is necessarily in an approximate
cal form, as all trigonometrical functions were replaced by
velopment in series, and only the first two terms retained.
t years later, in 1863, R. Clausius,† in one of the

optical axis; most of them also fail to bring out clearly the result of non-fulfilment, and none deal with the significance of the theorem in the presence of spherical aberration.

The following proof, simple as it is, seems to be free from these objections.

In fig. 1 let OZ be the optical axis of a system of lenses or mirrors, or both combined, no other restriction being imposed than that all the refracting or reflecting surfaces shall be continuous surfaces of rotation with OZ as axis, and the system therefore a "centred" one. The rays from O shall be allowed to enter the system through a narrow zone marked by the circle A with C (on OZ) as centre; after passing through the system they are assumed to emerge by the zone defined by the circle A′ with C′ as centre, and to come to a focus at O′. That all rays of such a zone must come to a common focus follows from the symmetry of the entire system round the axis OZ. For the same reason any one ray, such as O—A—A′—O′ must always remain in that plane containing the axis OZ in which it started from O; the angles β_1 and β_1' formed by the incident and emergent rays with the optical axis must be the same for all rays of the zone under consideration, and the paths of all such rays must be equal, both as to their entire length and as to corresponding constituent parts.

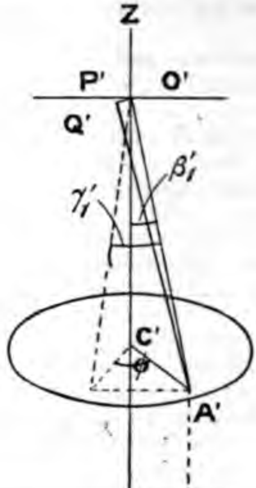
Owing to these properties of a centred optical system it is possible to discuss, without separate computation of the paths of rays through the system, the formation of the image of any point P near the optical axis, viz. so close to O that to any ray passing from O through the system we can find a corresponding ray from P which only forms small angles of the first order with it, and which does not become separated from it by more than small quantities of the first order anywhere within the system.

This generalisation depends on Fermat's theorem of the minimum optical path, according to which light passes from one point to another along the path which requires the least time* to traverse. For, according to the definition of a maximum or minimum, it follows at once that any path which agrees with a known optically determined path within small quantities of the *first* order is of the same length within small quantities not exceeding the *second* order, and is therefore sensibly equal to it. We are, therefore, justified in assuming that the paths traversed within the optical system by light from P are sensibly equal to those followed by light from O, and we can base our study of the image of P on a comparison of the paths outside the system.

In order that P′ may be the image of P all optical paths between P and P′ must be of equal length, for that is the

* In certain cases the path assigned to light by the laws of refraction and reflexion is the one which requires the *longest* time. Fermat's theorem, therefore, requires an extension. We must state that light passes from point to point along a path for which the time of transit is *an extreme value*, i.e. either a minimum or a maximum.

on under which all light from P will arrive at P′ in the
hase of vibration so as to form a bright image.



and by Fermat's theorem we need not consider the portion within the system.

Now OA and PA are two such corresponding rays, and by dropping a perpendicular PQ from P upon PA we see that PA is shorter than OA by OQ. On reference to the rectangular system of coordinates shown in fig. 1, P lying on the axis OX, it is seen that, γ_1 being the angle between OA and the YZ plane, we have

$$OQ = OP \, . \sin \gamma_1$$

Calling the angle between radius CA and the YZ plane ϕ, we further have

$$\sin \gamma_1 = \sin \phi \sin \beta_1$$

and therefore

$$(1) \quad OQ = OP \, . \sin \beta_1 \, . \sin \phi$$

The angle ϕ being the angle between the YZ plane and the plane in which the ray OA proceeds through the system is constant for this ray; hence, by analogy, we can at once write down that the quantity P′Q′ by which A′P′ is longer than A′O′ is given by

$$(2) \quad P'Q' = O'P' \sin \beta_1' \sin \phi$$

(1) and (2) give us the *geometrical* differences between the optical paths OAA′O′ and PAA′P′. But we must compare optical paths, *i.e.* we must bear in mind that the velocity of light is inversely proportional to the refractive index, and that the geometrical paths must, therefore, be multiplied by the index of the medium in which they lie in order to be commensurable. Taking the indices surrounding object and image respectively as n and n', we therefore get the difference of the optical paths O – O′ and P—P′ given by

$$n \, . \, \overline{OQ} - n' \, . \, \overline{P'Q'} = \sin \phi \, \{n \, . \, OP \, . \sin \beta_1 - n' \, . \, O'P' \sin \beta_1'\}$$

This difference varies, therefore, in general according to the value of ϕ. But it vanishes, and all optical paths between P and P′ become equal when the bracketed term becomes zero; hence a narrow zone of *any* centred optical system will yield sharp images of points not in but near the optical axis, and the position of the image is determined by the condition

$$(3) \quad n \, . \, \overline{OP} \, . \sin \beta_1 = n' \, . \, \overline{O'P'} \, . \sin \beta_1' \, ^*$$

$\dfrac{O'P'}{OP}$ is obviously the magnification of the image, for which we

* It is interesting to note the close resemblance of this equation to the so-called optical invariant OP . n . tan β_1 which is obtained in geometrical optics on the assumption of strictly collinear relation between object-space and image-space. The difference between the two proves that optical systems of wide aperture do not possess the property of collinearity.

oduce the symbol M. Introducing this, we arrive at the
ental equation

$$\text{I.} \quad M = \frac{n \sin \beta_1}{n' \sin \beta_1'},$$

hus expresses a universal property of centred optical
whether spherically corrected or not, and which in this
ty would seem to be new. Although I have not specially
upon it, it will be obvious that all the arguments used
valid, not only for the case graphically shown in fig. 1 of
nverted image, but also for virtual images, and even
the rays should cross the axis once or several times
he system.

ation I. at once becomes the sine-condition in its usual
assuming a spherically corrected system, we demand
zones of the system shall concentrate the light from P
ame point; for that is equivalent to demanding that all
hall have the same magnifying power. Hence, taking
β' as the general symbols for conjugate angles of con-
e of any ray before and after passing through the system,
the condition under which a system spherically corrected
optical axis will also correctly depict points *near* the
axis.

ənt zones will have different magnifying powers; they will :ore produce images of an extra-axial point which occupy ənt positions on a radial line, and which together form a nstead of a point. Hence there can be no distinct image t in the immediate vicinity of the optical axis. In telescope-:ives the differences of magnification that are possible with sual types are comparatively small; hence all of them ər fairly well when used *with eyepieces restricted to the :l axis.* But in microscope-objectives it is possible to ce systems which, whilst perfectly corrected for spherical :hromatic aberration in the optical axis, have differences gnification of as much as 50 per cent. between centre and in. Obviously this makes the formation of a recognisable) of an extra-axial point impossible, and we have therefore emarkable possibility of lens-systems the useful field of ı is of the same order as their resolving power, *i.e.* which t separate two points if placed symmetrically to the optical but which would break down if the object left the optical *ıt all.*

he importance of this theorem for photographic telescopes ; from the fact which has been repeatedly proved by very ious computations by the staff of Dr. Steinheil in Munich, telescope-objectives which *rigorously* fulfil the sine-condition ıce perfectly symmetrical images of stars up to the extreme ; of the usual astrographic field; hence the recommendation ə Paris Congress.

or telescopes the equation expressing the condition allows convenient modification. Telescopic objects are at a con-ıble distance from the instruments, so that β is a very angle, and their angular extent rather than their linear ıitude is known. Let δ be the angle subtended by OP as from A; then we can replace OP in equation (3) by its alent OA . δ and write

$$\mathrm{OA} \,.\, \delta \,.\, n \,.\, \sin\beta = \mathrm{O'P'} \,.\, n' \,.\, \sin\beta'$$

ə index of the medium surrounding the object, may for the ope be put $= 1$, and OA sin β is evidently the semi-aperture rhich we will call y. Hence we have the sine-condition for əlescope in the form

$$\text{III.} \quad \frac{y}{n' \sin\beta'} = \frac{\mathrm{O'P'}}{\delta} = \text{constant}$$

ce it is evident that with an object at a very great distance

$\overline{\text{in}\,\beta'}$ is equal to the equivalent focus of the lens-system; for

:he distance at which the image subtends the same angle as subtended by the object. Of course in most telescopes n' is qual to unity, the image being formed in air; but the more al form of III. includes such instruments as the one filled

ter which Airy used in a famous experiment concerning
tant of aberration.
to the significance of the sine-condition in systems
with spherical aberration, it may there be used to secure
rical images by so proportioning the magnification of the
zones to the distance from the lens-system at which
ne to a focus that all the cones have a common axis
2). As the longitudinal aberration of lens-systems of
e aperture—like the departure of successive zones from
-condition—is proportional to the second power of the
, this end can be completely attained in such cases.
tension of the theorem is important, as it can be used
ably to abridge the amount of computation necessary to
t a perfect lens, and also because in some cases spherical
on has to be sacrificed to other conditions.
paper may fittingly be closed with some remarks which
pply the answer to a question which will occur to many,

the "figuring" of mirrors. But it is otherwise with chromatic aberration. Sensibly to change the colour for which an objective has minimum focus means a very considerable alteration, one which it would be hopeless to try and effect by *any* polishing process; it means an alteration by turning and subsequent regrinding of the tools employed, and a complete reworking of at least one surface of the objective; or a still greater alteration of two surfaces if a given focus is to be maintained. And if the sine-condition is to be fulfilled, matters become even worse.

The well-known type of object-glass, for instance, which consists of an equi-convex crown and a practically plano-concave flint, offends against the sine-condition to the extent of a difference of magnification between centre and margin, which is of the small order of one-tenth of one per cent. Yet to correct this comparatively slight error and to secure images as symmetrical as should be demanded for photographic purposes, the crown-lens will have to be altered until the curvature of its outside is about half that of the inside, whilst the flint-glass will have assumed a pronounced meniscus-form, if indeed it should be at all possible to carry out so drastic an alteration without making the glasses too thin. In fact, it may be stated, without fear of serious contradiction, that it will always be a hard task to produce by rule of thumb an objective having *minimum focus for a prescribed wave-length*, and that it would be a hopeless enterprise to try to rigorously fulfil the sine-condition without careful computation.

On the Large Sun-spot of 1905 January 29–February 11, and Contemporaneous Magnetic Disturbances, observed at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer-Royal.*)

The largest sun-spot as yet photographed at the Royal Observatory, Greenwich, appeared at the east limb of the Sun on 1905 January 28, and passed off at the west limb on February 11. This was the rotation in which it attained its greatest dimensions; but it had been seen in the preceding rotation as well, and reappeared in the third rotation. It was first photographed at Greenwich on January 7, that day being the first occasion on which solar photographs were obtained this year. It is therefore not yet certain as to whether the group formed first in the visible hemisphere or in the one turned from us. If the latter, it would have come into view at the east limb on January 1. The group is now (March 10) completing its third rotation and passing out of sight at the west limb. The Sun was photographed at Greenwich upon five days during the first apparition of the group, upon ten days during the second,

n seven days during the third. The photographs taken the first two apparitions have all been measured and ; but there has been only time enough as yet to measure n during the third.

n first seen, on January 7, the group consisted of a l stream of rather small faint spots, the leader spot e only one at all dark or well defined. Many of the of these small spots disappeared on the succeeding days, anuary 12 only four small spots remained.

n .	Projected Area of Umbra.	Projected Area of Whole Spot.	Area for Group corrected for Foreshortening Umbra.	Area for Group corrected for Foreshortening Whole Spot.	Mean Longitude of Group.	Mean Latitude of Group.	Longitude from Central Meridian.
40	25	246	13	130	321°·5	−18°·2	−12°·0
01	25	167	17	112	323·4	−17·1	+40·7
71	12	85	12	77	324·3	−17·0	+55·7
73	11	119	16	155	323·7	−17·3	+68·3
40	0	7	0	15	320·3	−18·1	+77·7

projected areas are expressed in millionths of the Sun's

[redacted]

Date. Greenwich Civil Time.	Projected Area of Umbra.	Projected Area of Whole Spot.	Area for Group corrected for Foreshortening Umbra.	Area for Group corrected for Foreshortening Whole Spot.	Mean Longitude of Group.	Mean Latitude of Group.	Longitude from Central Meridian.
1905. d					°	°	°
Jan. 29·497	182	1771	327	3190	329·3	−15·7	−75·0
30·499	300	2690	310	2784	329·5	−15·6	−61·6
31·470	420	4222	320	3218	329·2	−15·6	−49·2
Feb. 1·461	641	5119	398	3180	329·8	−15·7	−35·5
2·451	935	6139	508	3339	329·9	−15·2	−22·3
3·458	1037	6293	532	3229	329·3	−15·6	−9·7
5·517	656	5221	348	2771	329·5	−14·8	+17·5
6·672	399	4321	235	2472	328·1	−14·7	+31·4
8·544	201	2664	179	2369	328·4	−14·7	+56·4
10·539	56	440	163	1252	327·2	−14·8	+81·3

The great spot could just be perceived as a very slight dark mark on the west limb on February 11, but it was not possible to measure it.

It was next photographed on February 25, when it had again returned to the east limb. It was now not nearly as large as during the preceding rotation, but was still a very fine group. Its form was now that of an extended stream, the principal spot being very large and complex, with two or three regular spots following it, and a few very small faint spots preceding it. The extreme length of the group on March 4 was 13° of solar longitude, its extreme breadth 5° of solar latitude.

Another great spot, but in the northern hemisphere, appeared at the east limb on March 1. This, like the group of January 28 to February 11, was a single spot of great complexity of detail. It was represented during the preceding rotation by quite a small group, a short stream at the head of a long scattered procession of groups following each other at considerable intervals. The same general region had been disturbed during December, but there does not seem to have been an unbroken persistence of actually the same spot-group.

This northern group showed a strong tendency to extend itself in longitude. On March 4 it had an extreme length in longitude of 15½°, on March 6 of 18°, its extreme breadth being about 7° of solar latitude. Up to the present only one photograph taken during the joint appearance of these two great spots has been measured and reduced. This was taken on March 4, when the areas and mean positions for the two groups were as follows:

Group, 1905 March 4.	Projected Area of Umbra.	Projected Area of Whole Spot.	Area for Group corrected for Foreshortening Umbra.	Area for Group corrected for Foreshortening Whole Spot.	Mean Longitude of Group.	Mean Latitude of Group.	Longitude from Central Meridian.
					°	°	°
Southern Group	305	2358	159	1224	330·3	−16·7	+12·8
Northern Group	242	3133	189	2447	270·3	+10·6	−47·2

following table gives the times when the Southern crossed the central meridian, and the angular distance n the centre of the group and the centre of the disc at e of transit :

Times of Transit across the ntral Meridian of the Southern Group.			Duration of Transit.	Distance of Centre from Centre of Disc.
.	Centre.	End.		
h	d h	d h	h	°
3	Jan. 8 10	Jan. 8 17	14	−14·2
4	Feb. 4 4	Feb. 4 18	28	− 9·3
0	Mar. 3 11	Mar. 4 0	24	− 9·4

successive times of transit of the centre of the group e intervals $26^d\ 18^h$, and $27^d\ 7^h$ for the observed synodic . The mean synodic rotation period for a spot in latitude s given by Carrington as $27^d\ 3^h$.

Northern Group would appear to have been in transit he following times :

f Transit across the C.M. of Northern Group.			Duration of Transit.	Distance of Centre from Centre of Disc.
.	Centre.	End.		
h	d h	d h	h	°
8	March 8 0	March 8 17	33	+17·8

Spectroscopic Observations of the Recent Great Sun-spot and Associated Prominences. By A. Fowler.

Introductory.

The great sun-spot which was so conspicuous during the last three days of January and the early part of February presented several features of interest when examined with the spectroscope, and it may be useful to give an account of the phenomena observed. Observations of the spectrum were made on January 31, February 1, 2, and 3, and after the return of the spot on February 25, 28, March 3 and 6. The prominences overlying the spot as it passed over the western limb on February 11 were also observed and the spectrum recorded in considerable detail.

All the observations were made with an Evershed solar spectroscope attached to a 6-inch refractor.

Reversals of Lines.

During the first passage of the spot across the disc the C and F lines of hydrogen were brightly reversed, but on its return the reversals were less pronounced and could not be seen at all on March 6. The D_3 line of helium was a prominent feature for a short time on February 2, and was also noted on February 25. Reversals of the sodium lines D_1 and D_2 were very conspicuous during the earlier stages, but were not seen after the return of the spot. The magnesium lines b_1, b_2, and b_4 and the iron line b_3 were observed to be reversed on January 31, and again, together with many other lines, on February 2. Details of the observations are as follows:

January 31 (9.50 A.M.–2.30 P.M.).—C and F were brilliantly reversed in numerous places over a large area, and especially over the greater part of the largest umbra. D_3 was suspected as a bright line. D_1 and D_2 were brightly reversed over the two largest umbræ, and the four *b* lines were seen bright on the inner edge of the principal umbra, where C and F were brightest. The displacements of the lines were very slight.

February 1 (11–11.20 A.M.).—C and F were reversed as on the previous day, but the displacement of the (dark) lines were more marked; the greatest displacement was about 2 tenth metres. D_3 was not observed, but D_1 and D_2 were reversed as on January 31.

February 2 (9.45–12).—From 9.45 to 10 A.M. there was an eruption over the spot, during which the C line in a region preceding the principal umbra was expanded into a cloudy form extending about 5 tenth metres towards the red; over the umbra the line was also brilliantly reversed, but occupied its normal position. D_3 was also very conspicuous, and, so far as

determined, its appearance was similar to that of the C
cept that it could not be traced quite so far from the
position : it changed from bright to dark as the position
pot upon the slit was varied.

ing this eruption, at the place where C, F, and D_3 were
rilliant, all the Fraunhofer lines seemed to be either
ted or reversed. There was only time to note the wave-
of a few of the bright lines but among them were
y the helium line 6678·3, the D lines of sodium, the
d line of iron 5316·79 (1474 K), the iron line 5269·7 (E_2),
b lines, and the enhanced iron lines 5018·6 and 4924·1;
re, in fact, among those most frequently observed in the
of metallic prominences on the Sun's limb. These bright
l not appear to be in the least displaced from their normal
s.

o A.M. the metallic lines had disappeared and the bright
over the umbra was greatly enfeebled, though it remained
for some time as a faint dark line in the region preceding
bra. At 11.10 A.M. D_3 was again seen as a bright line
e of the smaller umbræ at a place where the D lines were
ersed.

uary 3 (9.50–12.30).—Though reversed in many places
e spot area, C and F were nowhere very bright, and D_3

prominent in the peculiar group of small spots seen in the eastern hemisphere on February 22; it then appeared as a broken and contorted dark line resembling C and F.

The Widened Lines.

General examinations of the spectrum of the largest umbra indicated that the "most widened" or most strengthened lines were not notably different from those recently observed in other spots. In other words, the majority of the affected lines could be traced to vanadium, titanium, chromium, scandium, sodium, calcium, and iron.

Selected parts of the spectrum were examined very minutely, the intensities of the lines being estimated by comparison with the Fraunhofer lines outside the spot spectrum. The result of these observations is to indicate that the spectrum, apart from the superficial effects already described, was sensibly constant from day to day, and was not materially different from that of another spot observed on the same plan on January 18. Thus, out of forty-six lines recorded in the great spot on January 31 in the region 5170–5239·2 forty-four appeared in the record for the corresponding part of the spectrum on February 1, and thirty-five of the forty lines recorded on February 28 in the region 5198·9–5239·2 appeared also in the previous lists. In the spot of January 18 forty affected lines were noted in the region 5188–5266, and thirty-seven of these occur among the lines recorded in the same part of the spectrum of the great spot. Considering the difficulty attending the observations, the differences are probably not significant.

The Spot Bands and General Absorption.

The bands of the sun-spot spectrum in the red, near 6381 and 6390, as well as those in the region more refrangible than *b*, were very strongly marked in the larger umbræ, and were always seen when looked for.

In the earlier observations the resolution of the general band of absorption, as described by Young* and Dunér,† was seen very clearly, although I had previously believed the dispersion at my disposal inadequate to show it. Probably the large dimensions of the umbra rendered the structure more visible. The resolution was best displayed by the bright gaps which occur here and there among the closely crowded dark components, and, as already noted by the observers named, these bright gaps are of the same brightness as the undimmed photospheric spectrum outside the spot. The general appearance of the band was very similar to that of a complex banded spectrum, such as that of sulphur, in which the maxima or "heads" are not very pronounced.

* *American Jour. Sci.* 3rd series, vol. xxvi. p. 333 (1883).
† *Recherches sur la Rotation du Soleil* (Upsala, 1891).

ıvourable conditions Young and Dunér were able to
e dark components of the spot-band structure in the
of the disc outside the spot, but this was not clearly
ny observations; the same effect, however, is to some
dicated by the fact that in some cases, the bright gaps
ıe spaces between nebulous lines of low intensity tabu-
Rowland. Three examples are as follows :—

Bright Gaps in Spot Band.	Solar Lines (Rowland).		
	5160·42	00	N
5160·8	5160·55	0000	
	5161·01	0000	N
5201·6	5201·46	0000	N
	5201·77	0000	N
5259·4	5259·26	0000	N
	5259·66	000	N

accordingly not improbable that the absorbing vapour
chiefly responsible for the darkness of a spot is thinly
ed over the general surface of the Sun, and may account
of the very numerous faint lines of the Fraunhofer
. At all events the appearance of the spot-band is in

shown by the numbers, while "l" and "s" respectively indicate whether the lines were long or short; the third column shows the origins which seem to be most probable, taking account of intensities of the lines and recognising that enhanced lines are specially developed in the chromospheric spectrum; columns 4 and 5 indicate the frequency and brightness of the corresponding lines given by Young.* Following Sir Norman Lockyer, enhanced lines are indicated by the prefix "p," so that "p Fe" reads as "proto-iron," &c. These special lines have been chiefly identified by reference to the table of chromospheric lines given by Sir Norman Lockyer in the report on the eclipse of 1898 January 22.†

Wave-length.	Intensity and Character.	Probable Origin.	Young. Frequency.	Young. Brightness.	Remarks.
4861·53	100 l	H	100	80	F. Expanded on both sides.
4922·10	15 l	He	30	8	No attempt could be made to record all the bright lines in this region.
4924·11	25 l	p Fe	40	10	
5015·73	20 l	He	30	10	
5018·63	25 l	p Fe	30	15	
5167·50	20 l	Mg	20	10	b_4
5169·22	40 l	p Fe	40	25	b_3
5172·86	30 l	Mg	50	30	b_2
5183·79	40 l	Mg	50	35	b_1
5188·86 / 5189·02	15 s	p Ti / Ca	10	5	Not seen separately
5197·8	25 l	...	10	10	
5200·4	10 s	...	2	4	Possibly Cr.
5202·52	10 s	Fe	4	3	
5204·68 / 5204·77	15 s	Cr / Fe	4	5	Not seen separately.
5206·22	15 s	Cr, Ti	4	5	
5208·60	15 s	Cr	4	5	Both components were reversed.
5208·78	15 s	Fe			
5227·04	20 s	Fe,Cr	3	3	Both components were reversed.
5227·36	20 s	Fe			
5239·47	25 l	...	10	10	

* Scheiner's *Astronomical Spectroscopy*, pp. 423–426, and p. 184.
† *Phil. Trans.* vol. 197A, p. 151.

length.	Intensity and Character.	Probable Origin.	Young. Frequency.	Young. Brightness.	Remarks.
55·0	15 l	...	3	3	
69·72	30 s	Fe	10	2	E_2.
70·44 } 70·56 }	25 s	{ Ca Fe }	5	2	E_1. Not seen separately.
76·17 } 76·24 }	35 l	{ p Fe Cr }	10	10	Not seen separately.
34·28	25 l	...	10	2–6	Fraunhofer line assigned Rowland, but not by H
16·79	45 l	p Fe	100	2–20	"1474 K."
24·37	15 s	Fe	...	...	Not in Young's list.
25·46	20 l	...	2	2	Fraunhofer line assigned Rowland.
28·24	25 s	Fe	3	2	
28·70 }	15 s	{ Fe }	3	2	Not seen separately.

	Intensity and Character.	Probable Origin.	Young. Fre-quency.	Bright-ness.	Remarks.
·12	20 s	Ni	1	1	
·03	20 l	Sc	? 40	? 5	Probably Young's line 5525·9 (A°), which is wrongly corrected to 5528·64 (R) and attributed to Mg.
·06	35 l	...	50	12	Perhaps slightly less refrangible than 5535·0, but certainly not 5535·7 Ba; dark line attributed to Fe by Rowland.
					Definition poor from here, and eruption perhaps less active.
·87	95 l	He	100	90	D_3; very long and bright, and expanded in places.
·19	40 s-l	Na	25	2–10	D_2 A little longer than most of "short" lines, with brighter "hump."
·16	40 s-l	Na	25	2–10	D_1
·60	15 l	...	15	2– 5	
·94	20 s-l	Fe, Ba	15	3– 5	Moderate length, with brighter "hump."
·60	15 l	...	10	2	
·77	20 l	...	10	4	
·3	25 l	...	10	3	
·7	10 l	...	5	3	
·6	15 l	...	5	3	Dark line assigned to Fe by Rowland.
·9	25 l	...	10	2–10	
·60	20 l	p Fe	15	3–10	Author's identification.
·13	20 s-l	Ba, Fe	18	3–15	Moderate length, with hump.
·3	30 l	...	15	3–10	Perhaps a little more refrangible than dark line.
·05	100 l	H	100	100	C.
·3	35 l	He	25	10–50	
·5	35 l	He	100	5–20	

It will be seen that the above list is in close agreement with t of Young, so far as the two are comparable. In the region ween b_4 and 5363, included in Young's revision, there is, in t, only one line of intensity greater than 2 which does not ear in the table—namely, 5226·7 (5); and this may well have n missed in consequence of poor seeing when that region was ler observation. In the red end Young's line 6191·8 is the

ne of greater intensity than 3 which I did not record. hort iron lines of low intensity which I observed, probably ents of good seeing, are not given by Young, but two of cur in Lockyer's table of eclipse lines. The long line of m at 5527·03 is probably identical with a line observed ng, which has been assumed to be the adjacent magne-ne 5528·64 when correcting from the scale of Ångström to Rowland. I have seen it on other occasions in metallic ences, and am quite certain of its position. Notwithstand- generally higher intensities which I have assigned to the lines as compared with those given by Young, it would pear that the spectrum of the disturbed chromosphere is bly constant.

omparison with the flash spectrum, as recorded by pris- ameras, indicates that the long arcs of the eclipse spectra esented by long lines in the foregoing table, suggesting er a spot there is a general elevation of the chromospheric vith little intermingling.

ar as it is possible to make a comparison of the bright pheric lines of February 11 with the affected dark lines sly noted in the spot, it appears that the high level lines t among those intensified in the spot, while the common

disturbance occurring in the fifty years mentioned are separately given, arranged in half-monthly periods, these three sets of numbers being here combined to form the numbers in Table I. as given by observation; but as fifty years are apparently insufficient to produce uniformity, smoothed values have been added, found by twice taking in succession the means of three observed values.

TABLE I.

Number of Days of Magnetic Disturbance, 1848–97, *in Half-monthly Periods.*

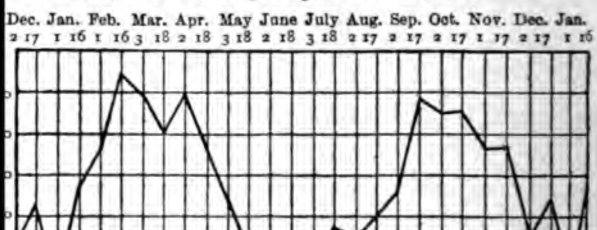
Middle Day of Half-monthly Period.	Total Number of Days of Moderate, Active, and Great Disturbance: As Observed.	As Smoothed.	Middle Day of Half-monthly Period.	Total Number of Days of Moderate, Active, and Great Disturbance: As Observed.	As Smoothed.
Jan. 1	116	146	July 3	121	127
16	165	163	18	145	136
Feb. 1	184	183	Aug. 2	140	143
16	219	200	17	149	156
Mar. 3	209	204	Sept. 2	162	171
18	189	200	17	209	190
Apr. 2	208	191	Oct. 2	202	197
18	178	176	17	203	197
May 3	155	156	Nov. 1	184	185
18	132	137	17	185	173
June 2	114	125	Dec. 2	139	155
18	119	123	17	156	148

The observed and smoothed values are graphically represented in the annexed diagram. Inspection of the smoothed numbers and smoothed curve alike shows that the points of maximum disturbance fall at about March 3 and October 9 respectively, the former in advance of the spring equinox by about the same number of days as the latter follows the autumn equinox. This close agreement in the interval of time—in the one case preceding the equinox by some seventeen days and in the other following the equinox by some seventeen days—may be, in a sense, accidental; and it will be interesting to see how far this result may afterwards be confirmed. As regards minima, that of summer appears to be much more pronounced than that of winter. The position of the points of maximum frequency of disturbance may possibly vary with the latitude of the place.

I have read with interest the paper by Mr. Maunder in which he endeavours to show the existence of direct relation between the rotation period of the Sun and the occurrence of terrestrial magnetic storms, and Professor Schuster's criticism thereof. Whatever may be the nature of any suggested explanation of their cause, it should satisfy established facts of observation. Perhaps I may be allowed to refer to some of

One circumstance is that active storms commence simul-
y over the whole earth—an accordance that has been
exist at stations widely separated both in latitude and
e. The first impulse is usually of the nature of a sudden
nore or less marked, in some cases being of extreme
But if the primary cause of magnetic storms be mainly
trial origin, how is the undoubted general relation with
variation to be explained? Another matter is the
spoken of seasonal variation in the frequency of disturb-
isting in our latitude, and by analogy the existence of
seasonal variation (with maxima at the equinoxes) in
latitudes, whatever may be the nature of the variation

Seasonal Variation of Magnetic Disturbance.



of the places the information is interesting. The particulars are contained in Table II., which indicates that at Greenwich, in

TABLE II

Direction of First Movement in Magnetic Storms.

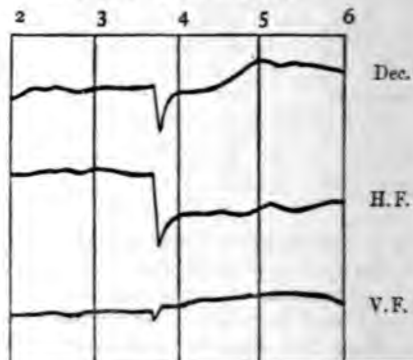
Place.	Number of Days		Direction of First Movement in		
	on which the Returns were Complete.	on which the First Movement was of Similar Character.	Dec.	Hor. Force.	Vert. Force.
Greenwich	14	11	+	+	+
Pawlowsk	9	6	+	+	+
Mauritius	11	7	−	+	+
Bombay	17	17	+	+	−
Batavia	15	15	+	+	−
Zi-ka-wei	4	4	−	+	−

eleven out of fourteen cases, and at Pawlowsk, in six out of nine cases, the first movement was such as to increase all elements; that at Mauritius, in seven out of eleven cases, declination was decreased and horizontal and vertical force increased; and that at Bombay and Batavia declination and horizontal force were increased and vertical force decreased for the whole of the instances, seventeen and fifteen respectively, in which the returns were complete. At Zi-ka-wei, in addition to the four cases in which the information was complete, on eleven other days there was indication for either one or two of the magnets, all in harmony with the movements for Zi-ka-wei given in the table. At Melbourne there was no special distinctive movement. These results would appear to be of some importance as showing that at the commencement of a magnetic storm the first impulse is in general similar: that is, that the Earth becomes affected usually in one definite way. This seems rather to raise the question whether the first shock over the whole Earth occurs when any particular face of the Earth is turned to the Sun. As mentioned in my first quoted paper, p. 151, I once tabulated to a considerable extent these initial movements according to the hour of Greenwich time, and remarked (p. 152) that there was some reason to think that storms commence more frequently when the Earth occupied a given position; but the inequality was not very striking—certainly there was no part of the twenty-four hours at which these movements were either unusually numerous or very scarce.

Another matter is that earth-currents (the spontaneous currents that arise in telegraph wires), which at times of quiet magnetism are very weak, become when a magnetic storm arises powerful. The two phenomena are connected in the most striking manner. But a solitary magnetic movement, even if it be not great, only it be sudden or abrupt (the essential feature),

at once accompanied by an equally abrupt earth-current
es isolated instances of this feature arise. An interesting
tion of a case of this kind, showing the close relation that
on such occasions between magnetic and earth-current
ents, is that occurring at Greenwich on 1893 February 14
^{m} in the morning, when the isolated magnetic movements,
not large (in declination only four minutes of arc), were

1893 *February* 14, *Morning.*



ated magnetic
and
arth current
movement
ecorded at

photographic defects; while the fact of its positions being in accord with those of a satellite for a period of over eight weeks renders the hypothesis of its being a minor planet extremely improbable, though perhaps not absolutely impossible. Under these circumstances, and in view of the fact that the Lick observers are waiting for further observations before publishing definitive elements, it seems worth while to give a rough approximation to the orbit, which I have deduced from the material already available: this is quite insufficient to deduce the eccentricity, so that the orbit is necessarily assumed to be circular.

The following table contains all the available material:

1904 December 3, 8, 9, 10.—Satellite west of *Jupiter* and receding from it.

1904 December 25.—West elongation, distance about 50′.

1905 January 4·7 G.M.T.—Distance 45′, position-angle 269°. Approaching *Jupiter* 45″ daily.

1905 January 17·7 G.M.T.—Distance 36′, position-angle 266°.

1905 January 28.—Approaching *Jupiter* about 1′ daily.

Taking first the elongation distance as exactly 50′, I examined how nearly this would represent the positions on January 4 and 17. It is necessary to do this independently on the two hypotheses of direct and retrograde orbital motion, since we cannot as yet distinguish between these. I may remark that the Lick astronomers have now definitely stated that the phrase "apparent motion retrograde" in the original telegram had reference only to the diminishing position-angle; it was fairly obvious from the nature of the case that this must be so, though several astronomers interpreted it as referring to the orbital motion. It may perhaps be suggested that the words "position-angle diminishing" should be used in similar cases in the future to avoid all ambiguity. An elongation distance of 50′ on 1904 December 25 implies that the distance of the satellite from *Jupiter* is 0·0668 in astronomical units, or about 6,200,000 miles, the corresponding sidereal period being 204 days.

From these data the computed angular distances from *Jupiter* are as follows:

G.M.T.	Computed Distance.		Observed Distance.
	Direct Orbit.	Retrograde Orbit.	
1905 January 4·7	45′·8	46′·0	45′
17·7	35·4	34·3	36

It will be seen that the results are slightly more accordant on the "direct" hypothesis; but no stress can be laid on this, since the discordances may be due to eccentricity in the orbit or an error in the assumed epoch of elongation. It appears probable that the assumed distance of the satellite at elongation is correct within one or two per cent., and the observations do not permit of a more precise determination.

calculated rate of approach to *Jupiter* is 42″ daily on
4, 72″ on January 28, these values being tolerably
nt with the observed values given above.
nd the approximate position-angle of the apse it is suf-
o note that the linear velocity parallel to the minor axis
pparent ellipse, being a maximum at the apse, is nearly
for some days after this. This method gave 270°·7 as
ition-angle, which a second approximation altered to
The deduced minor semi-axis of the apparent ellipse on
er 25 is 4′·96.
be the angle between the line of sight on December 25
orbit plane, then $\sin\phi = \frac{4 \cdot 96}{50}$, and $\phi = 5^\circ \cdot 7$.
n to find the pole of the orbit plane we must proceed
e minor axis of the apparent ellipse (*i.e.* in position-angle
a distance of 84°·3 on the hypothesis of direct orbital
or 95°·7 on the retrograde hypothesis. The two points
dicated were marked on a large scale map, and their
s from the poles of *Jupiter's* equator and orbit were
d with the following results :

	Direct Hypothesis.	Retrograde Hypothesis.
n of satellite's orbit to plane of *Jupiter's* equator	26°·0	24°·7

considered to be in a class by itself; but it has now got companions, so that this subterfuge disappears. The substitution of names for numerals is certainly more poetic, and abbreviations may be devised which would take no more space in printing than the present notation (e.g. *Io.*, *Eu.*, *Gan.*, *Cal.* for the four old satellites).

It may help to realise the relative distances of satellites from their primaries to point out that the distances of satellites V. and VI. from *Jupiter* are comparable with those of *Mercury* and *Uranus* from the Sun, while those of *Mimas* and *Phœbe* are comparable with those of *Mercury* and *Neptune*.

Benvenue, 55 *Ulandi Road, Blackheath, S.E.:*
1905 *March* 8.

The Later Leonids of 1904 *November.*
By Rev. S. J. Johnson, M.A.

As most of the observations obtained of this shower relate to what was seen in the earlier hours of the morning of November 15 last, they may perhaps be supplemented by some notes on the meteors nearer sunrise, or between 3.30 and 5.30 A.M. A perfectly clear sky and the absence of even the crescent Moon of 1903 favoured the display. During the two hours aforesaid I noticed twenty-five meteors (not quite all Leonids) between 3.30 and 4.30, and thirteen between 4.30 and 5.30; but from the circumscribed portion of the heavens presented to the observer through obstructions and the delay occasioned by recording the tracks it would be probably correct to multiply this number by 4. This would make just 100 meteors in the two hours. Comparing with 1903, when I noticed fifty-three in $1\frac{1}{4}$ hour, equivalent to about sixty in two hours, and multiplying again by 4, we obtain 240 for the same hours in the morning in 1903. This makes the stream of 1903 two and a half times as plentiful as that of 1904. A noteworthy point was the intense green colour of the larger ones, probably magnesium. Eleven were = ordinary 1st-magnitude stars, one = *Vega*, two = ♃, and one = ♀. The three brightest meteors seen were $14^{d}\ 16^{h}\ 10^{m}$ = ♃, across *Com. Beren.* $175^\circ+28^\circ$ to $198^\circ+28^\circ$, $14^{d}\ 16^{h}\ 14^{m}$ = ♀, very green. From about $195^\circ+22^\circ$ to about $202^\circ+18^\circ$, $14^{d}\ 17^{h}\ 16\frac{1}{4}^{m}$ = ♃, across χ *Leonis,* almost to *Mars,* $155^\circ+19^\circ$ to $167^\circ+5^\circ$.

Melplash Vicarage, Bridport:
March 4.

ıt Nebula of ↓ Eridani. By Dr. Max Wolf, Assoc. R.A.S.

ve had much difficulty in securing a photograph of this
bula. It is situated somewhat too far south for our lati-
d between very bright stars, so that the sky here has
t been sufficiently clear for me to obtain a perfect image.
know if the nebula is known elsewhere—it is not in the
nor in the Index Catalogue. The small nebulæ 398 and
he Index Catalogue seem to be included in this enormous
as well as N.G.C. 1779, 1797, 1799, but they are all rela-
mall and difficult objects. Perhaps Professor Barnard
photographed this object.

nebula now reproduced is situated between λ *Orionis* and
ni, not far from the first-magnitude star β *Orionis*.

first traces of this nebula were found on a plate taken
January 16 with a 4-inch Millet portrait lens and with
sure. It appears on many plates, including those of 1894
er 24 (in the centre of the plate); 1896 February 3, 7;
bruary 3, 4, 10; 1900 March 1, &c., till 1904 Novem-
-all taken with smaller lenses up to 6 inches.

accompanying plate (15, Fig. 1) is from a photograph
ith the 16-inch Brashear lens on 1905 January 8, with

FIG. 1.

FIG. 2.

GREAT NEBULA OF ψ ERIDANI. DR. MAX WOLF, HEIDELBERG.

ψ Eridani, extending from S.S.W. to N.N.E. The clouds become dense near 63 *Eridani*, and reach to about 1° south of *β Eridani*. I give some coordinates taken from the *B.D. Atlas* :—

R.A. h m	N.P.D. ° ′	
4 53·3	100 17	Cloud.
56·7	98 37	Elliptical cloud.
59·5	97 23	Fan-shaped end near the middle of the plate.
57·0	96 53	Long wisp.
58·9	97 14	Cloud.
59·0	97 0	„
5 0·8	96 30	Fan-shaped cloud.
0·3	96 20	„ „

The star-like spot $5^h\ 0^m \cdot 3$, 96° 40′ seems on comparison with other plates not to be real.

To show more clearly the position of this nebula I give on plate 15, Fig. 2, a portion of a photograph taken with the 6-inch lens on 1904 November 16 by my assistant, Mr. Goetz. This plate was only exposed for $1^h\ 20^m$, yet by suitable printing the features of the nebula can be brought out without too much halo round the bright stars.

The large white spot on the left of the plate is the glare from *β Orionis*; at the top is *β Eridani*, at right of the centre *ψ Eridani*. We here see very well between the bright stars the long track of the nebula extending from *β Eridani* to 63 *Eridani*. This reproduction shows that the stream of nebulosity forms in its northern parts the brighter boundary of an extended nebulous region involving *ψ Eridani*. The southern portion spreads around 63 *Eridani*, and is divided by complicated channels. The denser spot north-east near the star 90 of the chart is on all plates taken with the Voigtländer lens, but not well shown on those taken with the 16-inch—perhaps because too near the edge of the plate.

It is seen that nebulous patches are spread over several parts of the plate, forming connexions with the S and Y districts of the *Orion* system. The scale of the plate is about 9 cm. to 1°.

The intensity of the Z nebulæ is relatively great. They come out with less than an hour's exposure. The brighter parts east of *ψ Eridani* are almost equal in intensity to the D nebulæ in their parts east of *σ Orionis*.

The *ψ Eridani* nebula would be a beautiful object for a reflector, especially in more southern latitudes.

Königstuhl, Astrophysical Observatory:
1905 *February* 20.

the Publication of Astronomical Papers, with special ce to the International Catalogue. By W. W. Bryant.

as been suggested that in view of the approaching ice on the International Catalogue of Scientific Litera- ich was to take place when the scheme had been working years a few notes on the practical working of it would be eful to the Regional Bureau, which in the case of nical papers published in the United Kingdom is the Astronomical Society, represented by a committee, and best form for these notes would be a short paper pre- o the Society.

dertook this the more readily as I have had to deal with king of the schedule and instructions, not only for the Kingdom, but also indirectly for the whole world, as I ised all the slips sent in for the three volumes already nd have also had the opportunity of testing the applica- the same schedule to a great deal of literature already d before the commencement of the International ie.

most important point on which I desire to lay stress is easing need for centralisation of special scientific litera-

their special science, and to them articles meant to popularise science with the general reader do not appeal. They have their publishers and their public, and will not suffer appreciably. Books, of course, are few in number, and will not be affected by the proposal. As regards another class of publication, original observations, often of value, are made by people who desire prompt and unquestioning publication. Their purpose being thus served what is to prevent them from sending in complete series to our Society or elsewhere if they desire scientific recognition? Some of them already do this, and in one department, as is well known, one of our Fellows, Mr. Denning, to a great extent does it for them. And this brings me to the partial disposal of the second objection mentioned above. I think the scientific editors of the "standard" periodicals (or the secretaries and council of the Societies in the case of publications by Societies) would find practically no difficulty in carrying out my suggestion, if the original authors will go so far as to submit their papers and observations.

One more word as to accessibility. It has been necessary in the Royal Society Catalogue work to send a small staff of indexers and assistants to the British Museum and the Natural History Museum to get at some publications not to be found at Burlington House. This not only involves a great amount of time, but invites the question as to whether it is worth while indexing papers so difficult to unearth. The difficulty was probably not foreseen at the time of publication, but there is no excuse for not guarding against a repetition of it in the future.

Royal Observatory, Greenwich:
1905 *March.*

gives the results of the measures. The planet was at
bserved, so that the centre of the disc was chosen as
n Noon Ephemeris of the *Nautical Almanac* have been
n of the table.

ranus.

Parallax orrections. α.	δ.	Concluded Geocentric Apparent Places of Planet. α.	δ.	Obs.–Cal. α.	δ.
s	″	h m s	° ′ ″	s	″
·01	−0·1	17 46 17·08	−23 37 3·9	0·00	−0·1
·02	−0·1	17 46 8·44	−23 36 59·9	−0·01	+1·3
·02	−0·1	17 45 10·25	−23 36 42·1	+0·03	+0·6
·02	−0·1	17 44 47·44	−23 36 34·8	+0·02	+0·2
·02	−0·1	17 44 25·89	−23 36 27·4	+0·05	+0·2
·02	−0·1	17 44 19·04	−23 36 25·6	−0·01	−0·4
·02	−0·1	17 44 12·40	−23 36 22·4	+0·02	+0·4
·02	−0·1	17 43 59·39	−23 36 18·3	−0·09	−0·2

Star for 1904·0.

Authorities.

By C. J. Merfield.

The accompanying observations of *Uranus* and *Saturn* were obtained with the telescope attached to the circles of the meridian instrument of the Sydney Observatory.

The writer, who is at present under the direction of Mr. Lenehan, acting Government Astronomer, was able to secure these observations during the evening's work with this instrument.

The equatorial instrument of this observatory requires a thorough overhauling, which will be undertaken at an early date; when completed it is the intention to secure observations of minor planets, comets, and southern double stars. The present writer anticipates being able to undertake this work.

Uranus.

1904.	M.T. Sydney.	Δα.	Δδ.	Op.	α app.	δ app.	Log pΔ.	Star reductions to apparent.		Star.
	h m s	m s	′ ″		h m s	° ′ ″		s	″	
July 16	10 7 41	+8 4·99	+0 48·7	7 1	17 46 34·53	−23 37 9·8	0·1863$_n$	+3·18	+7·9	1
16	10 7 41	+0 43·56	...	7	17 46 34·56	...	...	3·19	...	4
18	9 59 31	+0 25·51	+1 50·7	7 1	17 46 16·51	−23 37 4·3	0·1864$_n$	3·19	8·4	4
26	9 26 57	+6 39·78	+1 16·7	7 1	17 45 9·28	−23 36 42·0	0·1867$_n$	3·14	7·7	1
26	9 26 57	+4 15·88	...	7	17 45 9·32	...	...	3·15	...	3
27	9 22 53	+6 32·20	...	7	17 45 1·70	...	...	3·14	...	1
27	9 22 53	+4 8·32	...	7	17 45 1·76	...	...	3·15	...	3
29	9 14 46	+6 17·40	+1 24·5	7 1	17 44 46·89	−23 36 34·3	0·1868$_n$	3·13	7·6	1
29	9 14 46	−1 4·13	...	7	17 44 46·83	...	...	3·15	...	4
Aug. 2	8 58 34	+5 48·90	+1 33·7	7 1	17 44 18·36	−23 36 25·1	0·1869$_n$	3·10	+7·6	1
2	8 58 34	+3 24·86	...	7	17 44 18·26	...	...	+3·11	...	3

1·71	−23 36 22·0	0·1869$_n$	3·09	+7·6	1
1·73	...	...	3·10	...	3
1·71	...	...	3·11	...	4
58·93	−23 36 18·1	0·1869$_n$	3·07	7·5	1
58·80	...	...	3·07	...	3
59·02	...	...	3·10	...	4
29·88	−23 36 6·0	0·1871$_n$	3·02	7·4	1
30·18	...	...	3·03	...	3
30·08	...	...	3·05	...	4
15·14	−23 36 1·5	0·1871$_n$	2·98	7·4	1
(15·05)	...	...	2·98	...	(2)
14·97	...	...	2·99	...	3
15·02	...	...	3·01	...	4
1·43	−23 35 55·6	0·1872$_n$	2·94	7·4	1
1·39	...	...	2·95	...	3
1·53	...	...	2·97	...	4
57·42	−23 35 53·8	0·1872$_n$	2·93	+7·4	1

1904	M.T. Sydney.	Δα.	Δδ.	Op.	α app.	δ app.				Star
	h m s	m s	′ ″		h m s	° ′ ″		s	″	
Aug. 20	7 46 16	+1 53·27	...	7	17 42 46·46	...	...	+2·90	...	3
20	7 46 16	−3 4·25	+3 4·9	7 1	17 42 46·48	−23 35 50·7	0·1873$_n$	2·92	+7·8	4
22	7 38 19	+4 11·93	+2 11·1	7 1	17 42 41·15	−23 35 48·0	0·1873$_n$	2·86	7·3	1
22	7 38 19	+1 47·93	...	7	17 42 41·09	...	...	2·87	...	3
23	7 34 19	−3 13·25	+3 9·0	7 1	17 42 37·43	−23 35 46·6	0·1873$_n$	+2·87	+7·8	4

Mean Places of Comparison Stars.

Star.	α 1904.	δ 1904.	Authorities.
	h m s	° ′ ″	
1	17 38 26·36	−23 38 6·4	Cape 1850; Yarnall 1860; Argent. Gen. Cat. 1875; Paris 1875; Cape 1880.
2	17 39 39·42	...	Cape D.M. 23°, 6642.
3	17 40 50·29	−23 38 46·8	Yarnall 1860; Argent. Gen. Cat. 1875.
4	17 45 47·81	−23 39 3·4	Madras 1835; Argl. 1850; Argent. Gen. Cat. 1875; Cord. Z.C. 1875; Paris 1875; Radcliffe 1890.

Saturn.

1904.	M.T. Sydney.	Δα.	Δδ.	Op.	α app.	δ app.	Log pΔ$_s$.	Star reductions to apparent.		Star.
	h m s	m s	′ ″		h m s	° ′ ″		s	″	
Oct. 3	8 22 46	+8 56·25	+0 21·9	7 1	21 9 32·24	−17 36 12·5	0·3864$_n$	+2·86	+18·3	1
24	6 59 25	+8 10·09	−2 10·3	7 1	21 8 45·75	−17 38 45·9	0·3853$_n$	+2·53	+17·1	1
25	6 55 32	+8 12·51	−1 57·4	7 1	21 8 48·15	−17 38 33·1	0·3854$_n$	+2·51	+17·0	1
31	6 32 18	+8 34·49	−0 3·6	7 1	21 9 10·03	−17 36 39·6	0·3862$_n$	+2·41	+16·7	1

Mean Place of Comparison Star.

Star.	α 1904.	δ 1904.	Authority.
	h m s	° ′ ″	
1	21 0 33·13	−17 36 52·7	*Nautical Almanac*, 1904 (θ Capricorni). The correction +0ˢ·019 has been applied to α 1904. *See* Clock Star List 1904, Royal Observatory, Greenwich.

parison of Observations with the Mean Time Ephemerides of the Nautical Almanac.

URANUS.

$d\alpha$	$d\delta$	Date 1904.	$d\alpha$	$d\delta$
s	″		s	″
+0·10	−1·0	Aug. 10	+0·04	+1·0
+0·07	−0·8	13	+0·15	−0·4
−0·13	+0·4	16	−0·08	+0·2
+0·05	...	17	0·00	+0·4
+0·24	+0·4	20	−0·05	−0·9
−0·07	−0·3	22	+0·90	−0·8
−0·01	+0·5	23	+0·04	−0·7
0·00	−0·3			

SATURN.

Date 1904.	$d\alpha$	$d\delta$
Oct. 3	−0·09	+0·7
24	−0·12	+0·3
25	+0·06	+0·6
31	+0·07	+1·3

[redacted]

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

'OL. LXV. APRIL 14, 1905. No. 6

W. H. MAW, Esq., PRESIDENT, in the Chair.

William Bowyer, Royal Observatory, Greenwich; and 12 Maidenstone Hill, Greenwich, S.E.;
Rev. Thomas Joseph Charlton, The Rectory, Omeath, co. Louth, Ireland;
Capt. Louis Arthur Demers, Marine and Fisheries Department, Ottawa, Canada;
David James Reginald Edney, Royal Observatory, Greenwich, and Teston Lodge, Blackheath Rise, Lewisham, S.E.;
Herbert Henry Furner, Royal Observatory, Greenwich; and 7 Circus Street, Greenwich, S.E.;
John Adelbert Parkhurst, M.Sc., Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.;
Montagu Austin Phillips, F.R.G.S., F.Z.S., F.E.S., 22 Petherton Road, Highbury New Park, N.; and
Arthur L. Wood, H.M.S. "Conway," Rock Ferry, Birkenhead,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Major B. F. S. Baden-Powell, 32 Prince's Gate, S.W. (proposed by W. J. S. Lockyer);
Joseph Henry Elgie, 72 Grange Avenue, Leeds (proposed by C T. Whitmell);

ederick William Longbottom, Haslemere, Queen's Park, Chester (proposed by W. E. Plummer);
ederick John Marrian Stratton, B.A., Isaac Newton Student in the University of Cambridge, Caius College, Cambridge (proposed by Sir R. S. Ball); and
hn Willis, late India Office, retired, Merkara, 19 Bouverie Square, Folkestone (proposed by Sir R. S. Ball).

e following were proposed by the Council as Associates of ciety :—

eodor Albrecht, Königlich-preussische geodätische Institut, Berlin-Potsdam, Germany;
stav Müller, Astrophysikalisches Observatorium, Potsdam, Germany; and
dolphe Radau, Membre de l'Institut, Paris.

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venty-one presents were announced as having been re- since the last meeting, including, amongst others :—

tronomical Discovery, by H. H. Turner, presented by the

of the importance of the disturbances, whilst the fact that the selection had been wholly his, and had been made long before my paper, and therefore wholly independently of it, prevented the possibility of any bias in favour of what I may call the "Interval-Relation" having had anything to do with their selection.

In the following catalogue, therefore, the second and third columns are copied precisely from Mr. Ellis's catalogue, and the grouping of different disturbed days into continuous storms is also entirely his. In no case have I permitted myself to make any alteration in his list, although, since it was made for quite a different purpose from that for which I am now using it, in some cases an alteration of his grouping might legitimately have been made. I have only reproduced here the first thirty-four years of the entire collection of fifty-five which Mr. Ellis prepared, as the last twenty-one years have already been dealt with in Table I. of my former paper, and the differences between his catalogue for these years and mine are quite unimportant. In a few cases where he has included disturbances of a slightly smaller amplitude or simpler character than those exhibited in the Greenwich Plates the sequences brought out in Table I. are extended and completed, and so the evidence for the relation, to which I have called attention, is somewhat strengthened; but in general the two catalogues are in very close accord for the years which they have in common.

Dr. Charles Chree, F.R.S., has very kindly given me every facility for consulting the Kew registers for the occasions upon which the Greenwich registration was at fault. The catalogue is therefore complete, with the exception of five days before the Kew photographic records were commenced.

In the second column disturbances in which the greatest amplitude of movement in declination exceeded one degree of arc are indicated by the letter "G" for "great"; those movements exceeding thirty minutes are indicated by the letter "A" for "active"; the remaining disturbances are classed by Mr. Ellis as "moderate," with maximum movements of about twenty minutes up to thirty. As Mr. Ellis's catalogue only gave the days of disturbance, and not the times at which the disturbances began and ended, I had to take these out from the original sheets to the best of my judgment, and for the fourth and fifth columns of the catalogue I am therefore responsible. I have also added, as in Table I. of my earlier paper, the number of the solar rotation, and the heliographic longitude of the centre of the Sun's disc; the same numeration of the rotations, the same prime meridian and rotation period, being adopted as in the Heliographic Results given in the annual volumes of the Greenwich observations. For the earlier years I have numbered the rotations backwards from the Greenwich fundamental rotation—namely, that commencing 1853 November 9, which is No. 1 in the Greenwich numeration. The Sun's sidereal period of

has been assumed to be 25·38 days, corresponding to synodic rotation of 27·275 days; the longitude of the ng node has been assumed as 73° 40′ for 1850·0, and the n which passed through the ascending node at the epoch has been taken as the prime meridian. The times in logue are Greenwich mean solar time throughout, since is took the astronomical day, not the civil day, as his Hence the times should be increased by twelve hours to hem comparable with those given in Table I. of my paper, wherein I used Greenwich civil time.

TABLE IX.

G.M.T. of Commencement of Disturbance. d	h	Duration. h	No. of Rotation.	Longitude of Sun's Centre. °	Ref. No.	Class.	Days of Disturbance. 1848.	G.M.T. of Commencement of Disturbance. d	h	Duration. h	No. of Rotation.
14	6	7	−77	344·2	18	G	Nov. 17	16	22	...	−66
16	2	13	...	320·0	...	A	18	...		45	...
28	4	19	...	161·0	19	A	21	21	5	9	...
14	8	7	−76	294·9	20		26	26	10	14	...

Days of Disturbance.	G.M.T. of Commencement of Disturbance. d	h	Duration. h	No. of Rotation.	Longitude of Sun's Centre. °
1850. July 12	...		30	...	...
Oct. 1	1	1	...	−41	225·1
2	...		41	...	...
1851. Jan. 16	16	1	16	−37	254·7
19	19	9	20	...	210·8
Feb. 5	5	8	6	−36	347·6
18	18	2	16	...	179·7
July 14	14	7	13	−31	48·1
Aug. 24	24	6	4	−29	226·5
Sept. 3	3	18	...	...	87·8
4	...		27	...	...
6	6	2	...	...	56·9
7	...		41	...	...
27	27	1	11	−28	140·3
29	29	3	20	...	112·8
Oct. 1	1	7	...	...	84·2
2	...		38	...	...
28	28	9	14	−27	86·9
Nov. 11	11	9	4	−26	262·3
Dec. 6	6	7	10	−25	293·9
28	28	3	...	...	6·3
29	...		42	...	...
1852. Jan. 4	3	22	48	−24	276·8
19	19	11	...	...	72·2
20	...		36	...	...
Feb. 14	14	21	...	−23	84·3
15	...		27	...	...
17	17	0	...	...	47·0
18	...		...	...	...
19	...		71	...	...
21	20	23	16	...	4·2
Mar. 26	26	5	20	−21	272·9
31	31	7	11	...	205·8
Apr. 8	8	7	4	...	100·3
20	20	3	...	−20	304·0
21	...		...	...	...

Ref. No.	Class.	Days of Disturbance.	G.M.T. of Commencement of Disturbance. d	h	Duration. h	No. of Rotation.	Longitude of Sun's Centre. °
...	A	1852. Apr. 22	...		66	...	...
63	A	May 27	27	5	18	−19	173·3
64	A	June 11	11	4	13	−18	335·7
65		July 10	10	3	13	−17	312·4
66		Sept. 29	No reg.		No reg.	−14	317 ±
67	A	Oct. 18	18	4	3	...	70·8
68		20	20	0	17	...	46·6
69	G	Nov. 11	11	7	18	−13	112·7
70		13	13	2	21	...	89·1
71		Dec. 10	10	6	12	−12	91·0
72		23	23	8	10	−11	278·7
73		29	No reg.		No reg.	...	197 ±
74		1853. Jan. 10	10	4	9	...	43·8
75		Mar. 7	6	17	...	−9	32·4
...		8	...		62	...	...
76		17	17	7	6	−8	252·9
77		Apr. 5	5	2	48	...	5·1
78	A	May 24	24	5	18	−6	75·9
79	A	June 22	22	0	17	−5	54·9
80	G	July 12	12	1	20	−4	149·6
81	A	Sept. 1	1	14	...	−2	188·1
...	A	2	...		...	...	...
...		3	...		54	...	...
82		Oct. 31	31	4	7	0	121·8
83	A	Nov. 9	9	3	20	...	3·7
84	A	Dec. 6	6	0	24	+1	9·5
85	A	21	20	22	7	+2	172·9
86		1854. Jan. 2	No reg.		No reg.	...	7 ±
87		20	19	11	22	3	143·9
88		29	29	4	12	...	16·1
89		Feb. 15	15	4	...	4	152·2
...	A	16	...		57	...	...
90	G	24	24	5	...	...	33·1
...	A	25	...		56	...	...

of ...b-.	G.M.T. of Commencement of Disturbance. d	h	Duration. h	No. of Rotation.	Longitude of Sun's Centre. °
15	15	7	...	5	141·7
16	...		33	...	...
26	26	7	7	6	356·7
28	27	21	20	...	335·8
10	10	11	22	...	156·6
19	19	5	...	...	41·0
20	...		34	...	...
23	22	7	...	...	0·3
24	...		55	...	...
10	10	3	15	9	37·4
11	10	14	22	12	291·7
26	26	9	14	...	83·2
8	8	3	12	13	288·2
12	12	4	14	...	234·8
8	8	4	12	17	106·8

Ref. No.	Class.	Days of Disturbance. 1858.		G.M.T. of Commencement of Disturbance. d	h	Duration. h
121	A	Jan.	8	7	23	25
122	A	Feb.	16	16	7	...
...			17	...		34
123		Mar.	5	5	6	3
124			12	12	0	...
...	A		13	...		...
...	A		14	...		...
...			15	...		104
125			17	17	5	12
126			28	28	17	31
127	G	Apr.	9	8	13	...
...			10	...		53
128		May	7	7	9	34
129	A	June	22	22	9	...
...	A		23	...		...

Ref. No.	Class.	Days of Disturbance.	G.M.T. of Commencement of Disturbance. d	h	Duration. h	No. of Rotation.	Longitude of Sun's Centre. °
		1859.					
	A	June 8	7	19	29	75	124·4
	A	July 11	10	13	35	76	50·9
	G	Aug. 28	27	20	...	78	132·3
	A	29	...		52	...	...
	G	Sept. 1	1	2	...	...	76·1
	G	2	...		...	...	...
	G	3	...		...	...	...
	A	4	...		...	...	...
		5	...		130	...	...
		24	24	1	8	79	133·0
		Oct. 1	1	7	...	...	37·3
		2	...		34	...	...
		4	4	4	10	80	359·4
	G	12	12	14	24	...	248·3
	A	17	17	8	...	...	185·7
		18	...		49	...	...
		20	20	9	...	...	145·6
		21	...		34	...	...
		Dec. 5	5	6	34	82	260·8
	A	13	12	21	16	...	160·3
		1860.					
	A	Feb. 21	21	0	35	85	316·8
		Mar. 12	12	1	34	...	52·8
		27	27	17	...	86	206·2
	A	28	...		...	...	...
	A	29	...		54	...	...
	A	Apr. 9	8	21	24	...	45·7
	A	13	12	8	40	...	0·1
		June 10	10	13	9	89	297·2
	A	29	29	11	...	...	46·8
	A	30	...		...	...	...
	A	July 1	...		61	...	...
3	A	4	4	3	...	90	345·0
..		5	...		42	...	...
4	A	11	11	10	14	...	248·5
5		19	19	11	10	...	142·1
6	A	Aug. 6	6	16	...	91	261·3

Ref. No.	Class.	Days of Disturbance.	G.M.T. of Commencement of Disturbance. d	h	Duration. h	No. of Rotation.	Longitude of Sun's Centre. °
		1860.					
...	A	Aug. 7	...		...	...	...
...	A	8	...		...	...	...
...	A	9	...		...	...	...
...	G	10	...		...	...	...
...	A	11	...		...	...	...
...	G	12	...		167	...	...
167		16	16	2	19	...	136·8
168		30	30	2	19	92	311·8
169	G	Sept. 6	6	8	...	...	216·0
...	A	7	...		...	...	...
...		8	...		48	...	...
170		15	15	9	24	...	96·6
171		Dec. 10	10	0	24	95	47·5
172		16	15	12	30	96	335·0
		1861.					
173	A	Jan. 22	22	5	...	97	198·4
...		23	...		...	...	...
...	A	24	...		...	...	...
...	A	25	...		...	...	...
...	A	26	...		...	...	...
...		27	...		125	...	...
174	A	Feb. 27	26	23	...	98	87·6
...	A	28	...		49	...	...
175		Mar. 9	9	5	20	99	312·6
176		Apr. 15	15	3	19	100	185·7
177		Aug. 18	17	18	...	105	337·2
...		19	...		40	...	...
178	A	Oct. 10	10	21	19	107	342·6
179		24	23	20	30	...	171·7
180		Nov. 7	7	3	32	108	343·2
181	A	Dec. 19	19	3	...	109	149·7
...		20	...		37	...	...
		1862.					
182		Jan. 13	13	7	...	110	178·2
...		14	...		...	...	...
...	A	15	...		65	...	...
183	A	Feb. 21	20	21	17	111	30·2
184		Mar. 6	5	19	18	112	220·0

	G.M.T. of Commencement of Disturbance. d h	Duration. h	No. of Rotation.	Longitude of Sun's Centre. °
2	2 2	12	113	220·2
0	10 8	30	...	111·4
5	5 5	8	116	55·6
7	7 10	7	...	26·4
3	23 6	15	117	176·8
3	3 17	...	...	25·3
4	...	...	...	...
5	...	41	...	...
4	23 23	14	119	68·2
3	3 7	...	120	305·1
4	...	...	...	...
5	...	...	...	...
6	...	76	...	...
2	21 8	25	...	67·1
8	17 9	...	121	70·5

Ref. No.	Class.	Days of Disturbance.	G.M.T. of Commencement of Disturbance. d h	Duration. h	No. of Rotation.
		1863.			
210		Aug. 29	28 2	33	13
211	A	Sept. 9	9 6	...	...
...		10	...	40	...
212		23	23 6	...	13
...		24	...	30	...
213	A	Oct. 8	7 8	52	...
214		Nov. 6	5 7	28	13
215		14	14 1	...	13
...		15	...	36	...
		1864.			
216		Feb. 1	1 6	12	13
217		11	11 8	9	13
218		Mar. 6	6 6	32	13
219	A	10	10 3	...	..
...		11	...	40	..
220	A	Apr. 27	27 6	32	14

Class.	Days of Disturbance.		G.M.T. of Commencement of Disturbance.		Duration.	No. of Rotation.	Longitude of Sun's Centre.
	1865.		d	h	h		°
	Jan.	17	...		33	...	...
		25	25	2	10	151	317·1
	Feb.	15	15	6	10	151	38·4
A		17	16	23	...	...	15·9
A		18	...		...	...	...
		19	...		60	...	...
		21	21	2	...	152	321·6
		22	...		40	...	...
	Mar.	15	15	7	9	...	29·0
		20	20	3	15	153	325·3
	Apr.	17	16	6	...	154	327·4
		18	...		78	...	...
	May	14	13	7	30	155	330·0
A	June	10	9	11	37	156	330·6
G	Aug.	2	2	6	...	158	338·7
G		3	...		...	...	...
A		4	...		...	...	...
		5	...		83	...	...
A		10	10	6	13	...	232·9
		14	14	7	...	...	179·5
		1	...		28	...	...
	Oct.	4	4	17	...	160	220·5
A		5	...		...	...	...
		6	...		45	...	...
A		19	19	0	10	...	32·0
		26	26	3	7	161	298·0
		30	29	23	...	...	247·5
A		31	...		...	...	...
	Nov.	1	...		82	...	...
		3	3	5	7	...	191·4
	1866. Feb.	6	6	3	...	164	21·0
A		7	...		38	...	...
G		20	20	13	...	165	191·1
A		21	...		20	...	...
A		23	23	6	...	...	155·5
		24	...		...	...	...
A		25	...		53	...	...

Ref. No.	Class.	Days of Disturbance.		G.M.T. of Commencement of Disturbance.		Duration.	No. of Rotation.	Longitude of Sun's Centre.
		1866.		d	h	h		°
259		Mar.	7	6	8	32	...	9·5
260			18	18	7	19	166	211·9
261		Aug.	23	23	4	18	172	284·6
262		Sept.	9	9	5	8	...	59·5
263	A	Oct.	4	4	4	16	173	90·1
264			7	6	3	34	...	64·3
265			12	12	6	10	174	343·5
266		Nov.	26	26	3	12	175	111·7
		1867.						
267		Feb.	8	8	6	12	178	215·5
268			13	13	6	7	...	149·6
269		Mar.	6	6	5	...	179	233·5
...	A		7	...		...	...	...
...			8	...		55	...	...
270			10	10	6	9	...	180·3
271		May	28	28	7	11	182	216·4
272		June	1	1	11	10	...	161·3
273		Sept.	7	7	1	12	186	310·6
274			25	25	4	16	...	71·3
275		Oct.	2	2	7	18	187	337·3
		1868.						
276		Feb.	20	20	5	10	192	280·4
277		Mar.	20	19	15	32	193	266·0
278			30	30	9	9	...	124·2
279		Apr.	1	1	10	...	...	97·3
...			2	...		28	...	...
280			19	18	11	28	194	232·3
281	A		27	27	6	9	...	116·2
282			29	29	5	16	...	90·3
283		June	29	29	12	7	197	359·4
284	A	July	10	10	2	22	...	219·3
285			14	14	13	10	...	160·3
286	A	Aug.	30	30	6	17	199	262·7
287	A	Sept.	15	15	13	12	...	47·6
288			27	27	5	17	200	253·6
289	G		30	30	6	14	...	213·5
290		Oct.	19	19	4	11	201	323·9
291	A		22	22		20	...	284·9

	G.M.T. of Commencement of Disturbance. d	h	Duration. h	No. of Rotation.	Longitude of Sun's Centre.
[illegible]	24	3	...	...	258°·5
5	...		45	...	...
9	19	4	12	202	275·1
1	20	12	20	204	174·0
2	2	11	...	...	3·4
3	...		...	...	...
4	...		53	...	...
9	9	7	...	206	264·6
10	...		32	...	...
18	18	1	10	...	149·3
2	2	5	12	207	309·3
8	8	5	13	...	230·1
15	14	23	...	...	141·0
16	...		42	...	...
13	13	2	12	208	129·3

Ref. No.	Class.	Days of Disturbance. 1870.		G.M.T. of Commenceme[nt] of Disturban[ce]. d	h
318		Jan.	3	2	14
...			4	...	
319			30	29	10
320	G		32	31	23
321	A	Feb.	11	11	7
322			23	22	9
323	A	Mar.	21	21	12
324	A	Apr.	5	4	18
325			12	11	20
326			15	15	12
...			16	...	
327			21	21	4
328		May	15	14	15
329	G		20	19	23
330		June	12	12	5
331	A		16	16	18

ass.	Days of Disturbance.		G.M.T. of Commencement of Disturbance.		Duration.	No. of Rotation.	Longitude of Sun's Centre.
	1871.		d	h	h		°
A	Feb.	11	10	11	...	232	342·9
G		12	...		...	...	...
		13	...		71	...	...
		26	26	4	14	...	136·1
	Mar.	1	1	6	10	...	95·4
		22	22	8	...	233	177·6
A		23	...		28	...	...
		27	27	2	17	...	115·0
A	Apr.	1	1	8	16	...	45·7
G		9	9	5	...	234	301·8
		10	...		28	...	...
		13	13	9	12	...	246·8
A		17	17	7	...	...	195·1
A		18	...		31	...	...
		28	28	1	...	...	53·0
		29	...		50	...	...
G	June	17	17	12	14	236	105·6
A	July	21	21	13	...	237	15·0
		22	...		35	...	...
A	Aug.	6	6	1	10	238	170·0
		21	21	9	7	239	327·3
G		24	24	8	15	...	288·2
	Sept.	7	7	8	8	...	103·3
	Oct.	14	14	5	6	241	336·6
G	Nov.	2	1	6	34	...	98·7
A		9	9	7	...	242	352·7
G		10	...		34	...	...
		19	19	19	36	...	214·2
G	1872. Feb.	4	4	2	20	245	289·3
		19	19	13	13	...	85·7
	Mar.	1	1	14	17	246	300·3
A	Apr.	10	10	2	...	247	139·5
[illegible]		11	...		34	...	...
		15	14	15	...	...	79·5
[illegible]		16	...		46	...	...
[illegible]	June	3	3	2	10	249	145·6
[illegible]	July	7	7	5	...	250	53·9

Ref. No.	Class.	Days of Disturbance.		G.M.T. of Commencement of Disturbance.		Duration.	No. of Rotation.	Longitude of Sun's Centre.
		1872.		d	h	h		°
...	G	July	8	...		40	...	...
371			10	10	1	13	...	16·4
372			18	18	11	12	251	265·0
373			27	27	9	12	...	147·1
374	G	Aug.	3	3	4	...	...	57·2
...	A		4	...		48	...	...
375	A		8	8	7	16	252	349·5
376	A		14	14	6	24	...	270·7
377			25	25	7	8	...	124·8
378	A	Sept.	17	17	9	6	253	179·9
379		Oct.	5	5	11	14	254	301·3
380	G		14	14	10	...	...	183·1
...	A		15	...		...	...	...
...	A		16	...		...	...	...
...	G		17	...		...	...	...
...	A		18	...		96	...	...
381	A	Nov.	10	10	11	...	255	186·5
...			11	...		25	...	...
382		Dec.	9	9	8	12	256	166·0
383			14	14	4	9	...	102·3
384			17	17	1	13	...	64·4
385	A	1873. Jan.	3	3	4	12	257	198·8
386	A		5	5	7	...	...	170·8
...			6	...		...	...	...
...	A		7	...		68	...	...
387			25	25	0	...	258	271·4
...	•		26	...		...	...	...
...			27	...		60	...	...
388		Feb.	8	8	7	...	...	83·2
...	A		9	...		31	...	...
389	A	Mar.	8	8	3	...	259	76·6
...	A		9	...		...	...	...
...	A		10	...		85	...	...
390			23	23	4	16	260	238·3
391		Apr.	1	1	7	...	...	118·0
...			2	...		37	...	...
392	A		18	18	4	...	261	255·2

Ref. No.	Class.	Days of Disturbance.	G.M.T. of Commencement of Disturbance. d	h	Duration.	No. of Rotation.	Longitude of Sun's Centre.
		1873.	d	h	h		°
...		Apr. 19	...		37	...	...
393		May 15	15	7	19	262	256·7
394		23	23	8	19	...	150·3
395		32	31	18	30	...	39·0
396		June 20	20	5	12	263	141·4
397	A	26	26	7	10	...	60·9
398		29	29	11	12	...	19·0
399		July 9	9	7	14	264	248·8
400		12	12	5	14	...	210·2
401		16	16	6	15	...	156·7
402		23	23	4	9	...	65·2
403		Aug. 5	5	9	12	265	250·5
404		Sept. 20	20	4	13	266	5·6
		1874.					
405	A	Jan. 15	15	8	...	271	261·0
...		16	...		...	...	...
...	A	17	...		72	...	...
406		27	27	6	16	...	104·1
407	G	Feb. 4	4	1	...	...	1·6
...		5	...		36	...	...
408	A	Mar. 7	7	5	28	273	311·1
409	A	Apr. 1	1	11	...	274	338·2
...	A	2	...		25	...	...
410	A	7	7	8	12	...	260·7
411		13	13	4	10	...	183·7
412		28	28	12	20	275	341·1
413		May 26	25	18	30	276	340·8
414		June 3	3	8	9	...	227·2
415		Sept. 29	29	19	10	280	101·0
416	G	Oct. 3	3	2	...	...	57·5
...	A	4	...		...	...	...
...		5	...		62	...	...
417		16	16	3	18	281	245·5
		1875.					
418		Feb. 26	25	23	...	286	295·4
...		27	...		28	...	...
419		Apr. 7	7	4	14	287	125·3
420		26	26	5	9	288	233·8
421		May 6	6	3	11	...	102·8
422		Sept. 15	15	12	15	293	152·0

Ref. No.	Class.	Days of Disturbance.	G.M.T. of Commencement of Disturbance. d	h	Duration.	No. of Rotation.	Longitude of Sun's Centre.
		1876.	d	h	h		
423	A	Feb. 19	18	16	33	299	[illegible]
424		Oct. 23	23	3	9	308	[illegible]
425		Nov. 10	10	8	6	309	[illegible]
		1877.					
426		Jan. 6	6	5	10	311	[illegible]
427		May 2	2	7	11	315	[illegible]
428		11	10	21	12	...	[illegible]
429	A	28	28	6	15	316	[illegible]
430		Oct. 11	11	12	13	321	[illegible]
		1878.					
431		Jan. 23	23	13	12	325	[illegible]
432	A	June 3	2	20	20	329	[illegible]
		1879. None					
		1880.					
433		Mar. 17	17	5	7	353	[illegible]
434		May 2	2	3	17	355	[illegible]
435		Aug. 11	10	22	...	359	[illegible]
...	A	12	...		...	...	[illegible]
...	A	13	...		70	...	[illegible]
436		19	18	19	20	...	[illegible]
437		Sept. 14	14	13	...	360	[illegible]
...		15	...		27	...	[illegible]
438		27	27	11	10	...	
439		Oct. 25	25	7	...	362	[illegible]
...		26	...		34	...	[illegible]
440	A	Nov. 3	2	17	21	...	[illegible]
441		Dec. 19	19	0	12	364	[illegible]
		1881.					
442		Jan. 21	21	15	11	365	[illegible]
443	G	31	30	21	19	...	[illegible]
444		Mar. 3	2	11	16	366	[illegible]
445		Apr. 20	20	9	12	368	[illegible]
446	G	Sept. 12	12	1	...	373	
...	A	13	...		...	...	
...		14	...		60	...	
447		Nov. 8	8	1	...	375	
...		9	...		40	...	
448		23	23	6	18	376	
449		29	28	23	16	...	
450		Dec. 23	23	6	9	377	

It will be seen from Table IX. that the magnetic disturbances of the thirty-five years 1848 to 1881 show just the same kind of tendency to recur at intervals of about twenty-seven days as do the disturbances of the twenty-two years 1882 to 1903, given in Table I. in my former paper. More than seventy "sequences" are shown in all; most being, as with the sequences of Table I., pairs, *i.e.* the disturbance returns once after an interval of one or two solar rotations, but is not observed again. But there are several instances of longer duration, and these are given in Table X. Sequence LIII. is especially interesting, since in this case the disturbance was observed in eight successive rotations, the times of the returns being exceedingly regular. One of these returns is not included in Mr. Ellis's catalogue, the movement on this occasion falling very slightly below his adopted standard. A series of disturbances such as this, so regular in the time of return and so long continued, is sufficient in itself to establish the contention of my earlier paper that our magnetic disturbances are due to an action arising from restricted areas of the Sun's surface, and reaching the Earth along restricted stream-lines, not by a general radiation; and the demonstration is the more complete since for much of the time that the series was observed no other disturbances were in evidence.

Some of the other sequences in Table X. have been completed by the insertion of a disturbance not in Mr. Ellis's catalogue.

TABLE X.

Reference No. of Sequence.	No. of Rotation.	Reference No. of Disturbance.	Longitude of Centre of Sun's Disc.
LIII.	151	239	317°·1
	152	242	321·6
	153	244	325·3
	154	245	327·4
	155	246	330·0
	156	247	330·6
	157	...	332·1
	158	248	338·7
LIV.	119	191	68·2
	120	193	67·1
	121	194	70·5
	122	195	77·4
	123	197	78·5
	124	202	80·2
LV	−67	14	208°·8
	−66	...	...
	−65	21	202·8
	−64	22	198·9
LVI.	−24	55	72·2
	−23	56	84·3
	−22	...	...
	−21	61	100·3
LVII.	0	83	3·7
	1	84	9·5
	2	86	7 ±
	3	88	16·1

No. of Rotation.	Reference No. of Disturbance.	Longitude of Centre of Sun's Disc.
3	87	143°·9
4	89	152·2
5	91	141·7
6	94	156·6
105	177	337·2
106	...	...
107	178	342·6
108	180	343·2
141	220	319·6
142	222	309·3
143	224	293·2
144	225	309·7
146	229	161·9
147	231	167·9
148	233	173·0

Reference No. of Sequence.	No. of Rotation.	Reference No. of Disturbance.
LXIII.	219	322
	220	323
	221	...
	222	328
LXIV.	−29	45
	−28	49
	−27	50
LXV.	131	209
	132	211
	133	213
LXVI.	146	227
	147	230
	148	232
LXVII.	199	286
	200	288
	201	292

periods indicated by sun-spots. As a direct deduction from this observed relation, which for the sake of brevity and distinctness I will call the "Interval-Relation," it follows that there is a real connexion between the Sun and our disturbances; that the action of the Sun in that connexion is in each particular instance confined to a restricted area of the surface; and that the solar action is conveyed to us, not by radiation in all directions, but along restricted lines. I not only showed that the observed times of our magnetic disturbances indicated the existence of such stream-lines emanating from the Sun, but I showed that rays, restricted and defined, and thus analogous in form to those indicated by the disturbances, had been actually photographed as proceeding from restricted areas of the Sun. The existence, therefore, of such stream-lines is no more hypothetical or speculative than the existence of prominences, faculæ, or sun-spots themselves. In only one paragraph in my paper did I even refer to any speculative views, and then only for the purpose of illustration. In that case the speculation was not my own, and I was careful to preface my reference to it with the express disclaimer—"As to the physical cause of these streams and the condition of the matter composing them, it does not lie within my province to offer any suggestion" (*Monthly Notices*, vol. lxv. p. 33).

Nor did I express either directly or indirectly any opinion as to the source of the energy manifested in our magnetic storms.

It had been held—and high authority had been pleaded for the contention—that a direct connexion between the Sun and our magnetic disturbances was impossible unless we ascribed the energy manifested in them to an altogether impossible output of energy on the Sun. I showed that it followed simply from a consideration of the times at which the disturbances commenced that the solar action in them was altogether of a different kind from that which had been contemplated in this contention, and upon which the supposed output of energy had been calculated. I did not challenge the accuracy of the calculation, or in any way attempt to modify it; I simply showed that it had no bearing upon the case presented to us in nature. That calculation was irrelevant, and could not be taken into consideration. But beyond this I wrote no word bearing on the source of energy, whether it lay in the Sun, or in the Earth, or in some unknown region outside either. To remove the long "outstanding difficulty" it is sufficient that we now know that the actual method of action of the Sun is not that which had been contemplated, and upon which the calculation in question had been based.

I am able to write thus definitely with regard to the establishment of the chief contentions of my paper, since I find that there is a wide consensus of opinion that the Interval-Relation has been demonstrated, and it is no longer necessary for me to labour the point of its validity as if it were still in dispute. Professor Schuster says that an examination of my paper has convinced him "that, subject to certain qualifications,

under has made good his contention that magnetic
to recur in periods not differing much from that
otation of the sun-spot zones." Again, referring
ation, he says: "He [Mr. Maunder] has, no doubt, a
t" (*Monthly Notices*, vol. lxv. pp. 186, 197). The Rev
n a paper which is in the main unfavourable to m
, admits that "sequences undoubtedly exist" (*M*
vol. lxv. p. 203). Professor Larmor said that my
satisfied" him "that these magnetic storms somel
cur in a period which is nearly the same as the rota
"; and, referring to Plate I., fig. 4, of my paper, a
spection of the diagram throws more light on the
l the tables that could be invented" (*Observatory*
y, pp. 84, 85).

s granted then, that, as Professor Schuster puts i
ept it as proved that magnetic storms show some k
ity, the length of the period being somewhere near
Monthly Notices, vol. lxv. p. 189). There are onl
f which we know which could give rise to an inter
l—the Sun and the Moon. In the case of the Mo
e three months: the draconitic of 27·2122 day
of 27·3217 days, and the anomalistic of 27·5546
e at the following table, in which the sequences

…nce of …nce.	No. of Terms.	Apparent Drift in Longitude in a Rotation.	Apparent Daily Drift in Longitude.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Sidereal Rotation Period.
		°	′	d	′	d
…XIII.	2	+ 6·3	+ 13·9	26·806	864·9	24·972
…XV.	4	+ 4·3	+ 9·5	26·953	860·5	25·101
…VIII.	3	+ 4·3	+ 9·5	26·953	860·5	25·101
III.	2	+ 4·0	+ 8·8	26·975	859·9	25·119
I.	2	+ 3·9	+ 8·6	26·979	859·7	25·126
…LIV.	2	+ 3·7	+ 8·1	26·998	859·2	25·139
…XX.	2	+ 3·5	+ 7·7	27·012	858·8	25·152
…VIII.*	4	+ 3·2	+ 7·0	27·034	858·1	25·172
…XIX.	2	+ 2·8	+ 6·2	27·064	857·2	25·197
…XV.	2	+ 2·7	+ 5·9	27·072	857·0	25·204
LII.	2	+ 2·05	+ 4·5	27·121	855·6	25·246
XL.	2	+ 1·9	+ 4·2	27·131	855·3	25·255
…XIV.	2	+ 1·7	+ 3·7	27·147	854·8	25·268
…VIII.	2	+ 1·4	+ 3·1	27·169	854·2	25·288
…LIII.	2	+ 1·25	+ 2·8	27·181	853·8	25·298
IV.	2	+ 1·2	+ 2·6	27·184	853·7	25·300
…VII.	2	+ 0·9	+ 2·0	27·206	853·1	25·321
VII.	2	+ 0·65	+ 1·4	27·226	852·5	25·337
…XXI.	6	+ 0·2	+ 0·4	27·260	851·5	25·367
…LIX.	2	+ 0·05	+ 0·1	27·271	851·2	25·378
…XIII.	4	− 0·2	− 0·4	27·290	850·6	25·392
…VIII.	2	− 0·2	− 0·4	27·290	850·6	25·392
…XLV.	2	− 0·3	− 0·7	27·298	850·4	25·399
IX.	2	− 0·6	− 1·3	27·320	849·8	25·418
LI.	3	− 1·1	− 2·4	27·358	848·7	25·452
…XIV.	2	− 1·4	− 3·1	27·381	848·0	25·472
…XXI.	3	− 1·7	− 3·7	27·404	847·3	25·491
…XXI.	4	− 1·8	− 4·0	27·412	847·1	25·498
VII.	2	− 2·6	− 5·7	27·473	845·4	25·551
…LII.	2	− 2·7	− 5·9	27·481	845·1	25·558
…XX.	7	− 3·0	− 6·6	27·504	844·5	25·578
…VIII.	2	− 3·25	− 7·2	27·558	843·9	25·595
II.	3	− 4·6	− 10·1	27·628	841·0	25·688
XI.	2	− 5·0	− 11·0	27·659	840·1	25·712
…XIII.	2	− 6·0	− 13·2	27·737	837·9	25·779

* Increased to four terms by the inclusion of Disturbance No. 250.

	No. of Terms.	Apparent Drift in Longitude in a Rotation.	Apparent Daily Drift in Longitude.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Sidereal Rotation Period.
		°	′	d	′	d
I.	2	− 7·4	−16·3	27·847	834·8	25·874
V.	2	− 7·5	−16·5	27·855	834·6	25·881
I.	2	− 8·2	−18·0	27·911	833·0	25·929
I.	2	− 8·5	−18·7	27·934	832·4	25·949
X.	2	− 9·7	−21·3	28·031	829·7	26·032
L.	2	−10·15	−22·3	28·066	828·7	26·064
X.	2	−11·0	−24·2	28·135	826·9	26·122
I.	2	−12·6	−27·7	28·264	823·4	26·234
V.	2	−15·8	−34·8	28·565	816·3	26·460
X.	3	−16·5	−36·3	28·585	814·8	26·510

he above table I have included three sequences not given in my former paper. I give them here as illustrations of y in which I might have legitimately extended the number uences and their completeness if I had not preferred to he catalogue, which I had drawn up at the commencement inquiry, absolutely unaltered. It was, as I explained,

Ref. No. of Sequence.	Ref. No. of Disturbance in Table I.	Class.	Greenwich Civil Time of Commencement.				No. of Rotation.	Longitude of Sun's Centre.
					d	h		°
LXXI.	169	A	1893	June	18	13	531	232·7
	170	V		July	15	22	532	230·4
	...	M		Aug.	12	6	533	228·9
	174	M		Sept.	18	1	534	235·0
	...	M		Oct.	5	13	535	232·0
	177	V		Nov.	1	15	536	234·7
LXXII.	183	V	1894	Feb.	22	23	540	182·3
	186	M		Mar.	21	12	541	192·1
	188	V		Apr.	17	13	542	195·2
	...	M		May	14	19	543	216·0
	189	A		June	9	14	544	213·8

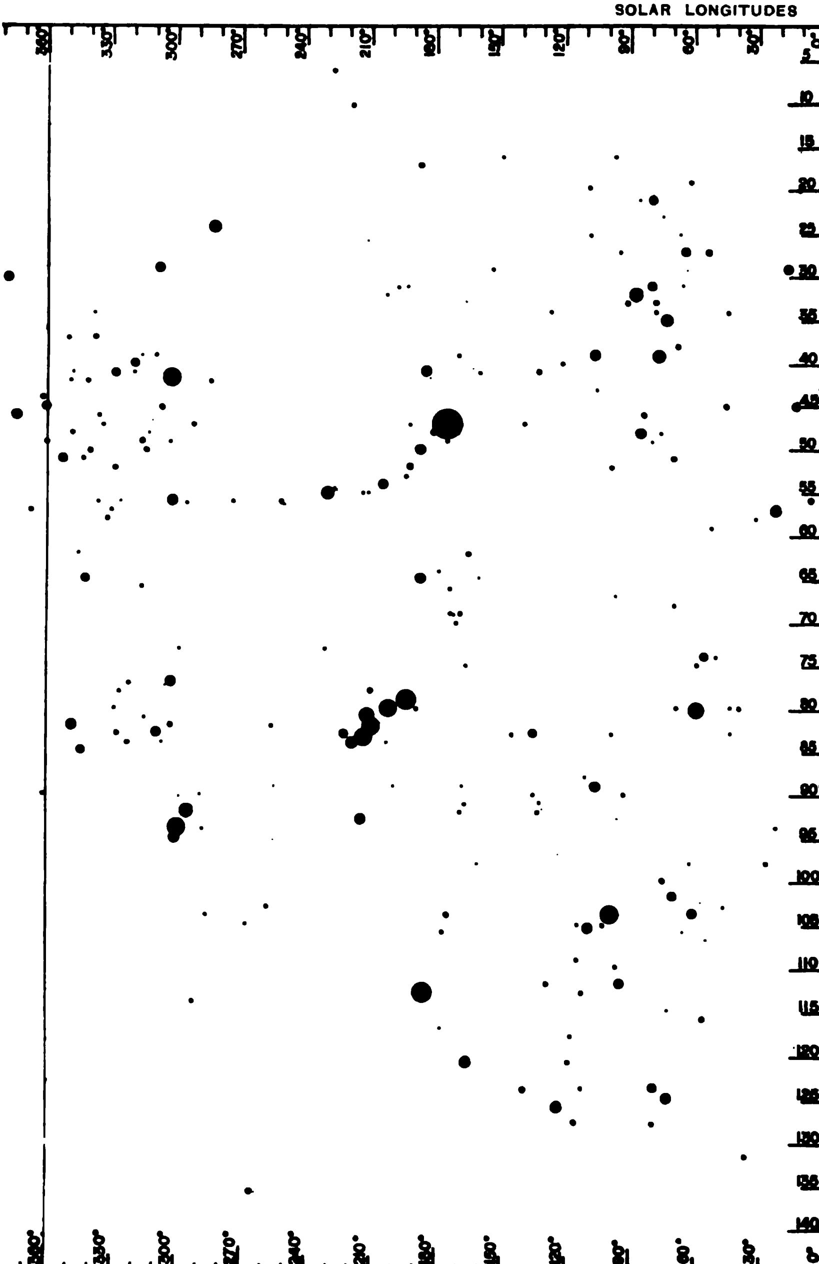
6. *The Distribution-Relation in Sun-spots.*

In my earlier paper I drew attention to a relation of the magnetic disturbances other than that which I have called the "Interval-Relation." For the sake of distinctness I will call this second relation the "Distribution-Relation." It was indeed the first point to which I called attention in referring to my diagram, fig. 4. ("Distribution of Magnetic Disturbances," *ibid.* vol. lxv. Plate 1.) I wrote (*Monthly Notices*, p. 18), "A mere inspection of the diagram brings out a striking and most important relation. The disturbances are not distributed irregularly with regard to the solar meridians, but chiefly affect one or two regions." I may say that to myself this was the most interesting result of my inquiry, although I considered that I was bound to defer enlarging upon it until I had demonstrated the Interval-Relation and the consequences arising from it. For this Distribution-Relation is distinct from that which I have termed the Interval-Relation, and is no necessary consequence of it. The latter I consider that I have now established; the Distribution-Relation, I think, is strongly suggested by my diagram, but I would by no means claim that it is proven.

I was therefore exceedingly gratified when Professor Larmor fixed upon this point as "a fact of extreme importance, even of more importance than the periodicity" (*Observatory*, 1905 February, p. 85). It was a further gratification to me that he also suggested that "it would be a very interesting thing if Mr. Maunder could show us diagrams like that one, each diagram classifying the sun-spots which occur in that narrow zone of latitude where the period of revolution shown by the sun-spots was something fairly definite," for that was precisely the work upon which my wife and I were employed when I came across the Interval-Relation.

As a very limited and partial example of the work upon which we have been engaged, we beg to submit the accompanying

. It shows all the spot groups, small and great, ephe-
nd long-lived, given in the Greenwich Heliographic
between the equator and north latitude 7·5 for the whole
ycle 1890–1902. The first group shown was observed
gust 8, the last 1901 July 8. There is no possibility of
etween one cycle and the next when limited zones in
are considered ; they are marked off from each other by
arren intervals of time, within which no spots whatever
in that particular zone. The last spot of the pre-
ycle was observed twenty-one rotations earlier, on 1890
6. The first spot of the new cycle, now in progress,
in this zone on 1904 April 11.
n the sun-spots of the different zones of latitude for the
89–1901 were charted down according to their longitudes
ced by Carrington's sidereal period of 25·38 days, corre-
g to a mean synodic period of 27·275 days (the rotation-
dopted at Greenwich), two narrow but well-marked
elts were observed to run in a slanting direction across
ram. We have therefore recomputed the mean longi-
r all these spot-groups with an assumed sidereal period
days, corresponding to a synodic period of 26·94 days.
riod is probably open to some slight correction, and it
perfectly borne in mind that any division of spot-groups



NORTH EQUATORIAL SPOTS, 0° TO + 7°.5;

THEIR DISTRIBUTION IN SOLAR LONGITUDE FOR THE CYCLE, 1891 TO 1902. SIDEREAL ROTATION PERI
, 25.09 *DAYS. DATE OF COMMENCEMENT OF ROTATION* No. 1: 1891 MARCH 18^d.76, GREENWICH CIVIL T

Solar Longitude.		Percentages of Total Areas.				Entire Cycle.
From	To	1891 Aug. 8 to 1895 July 17.	1895 Sept. 15 to 1896 Sept. 18.	1896 Oct. 18 to 1898 Feb. 26.	1898 May 22 to 1901 July 8.	
53°	68°	2·2	**22·9**	**6·8**	6·6	4·8
68	83	**12·6**	0·6	...	15·3	**8·0**
83	98	6·3	...	...	2·7	3·2
98	113	2·9	...	3·4	**24·1**	6·6
113	128	0·2	...	...	10·3	1·8
128	143	0·5	...	1·6	2·1	1·1
143	158	...	...	..	...	...
158	173	...	6·0	0·4	6·6	1·5
173	188	**35·3**	**49·4**	...	**29·8**	**22·1**
188	203	0·6	...	16·0	...	6·2
203	218	1·3	...	**35·6**	...	**13·4**
218	233	4·8	0·2	1·2	...	2·5
233	248	...	...	...	...	...
248	263	...	...	...	0·3	0·1
263	278	...	...	...	1·3	0·2
278	293	2·6	...	...	0·3	1·2
293	308	**10·9**	0·2	**25·1**	...	**14·0**
308	323	2·9	1·6	3·8	...	2·7
323	338	4·0	...	0·4	...	1·9
338	353	0·7	**18·1**	4·9	...	3·0

The first epoch begins with the commencement of the cycle 1891 August 8; but the spots are very sparse at first, and it is not until nearly a year later that the activity of the zone may be said to have really commenced. The epoch lasts until 1895 July 17, and is on the whole the most active of the four. The second epoch is one of almost complete quiescence, and lasts for a little over a year, its first spot being seen 1895 September 15, its last 1896 September 18. The third epoch is again one of great activity, extending from 1896 October 18 to 1898 February 23. The fourth and last epoch is one of decadence: its first spot was observed 1898 May 22, its last 1901 July 8.

Throughout all four of these epochs the three great regions of activity are clearly to be distinguished, but they are especially marked in the first and third. In the second epoch almost all the spots are contained in a narrow region extending over only 30° of longitude, and corresponding to the most active of the three centres. In the fourth epoch, for a period of very nearly three years, the entire spot-activity of the Sun is confined within 130° of longitude, leaving the remaining 230° almost absolutely void. This remarkable inequality seems to be due to the entire

nce of the second great region of activity and the marked
tion of the first centre, leaving the third in almost
e possession of the field.

se three great centres of activity are marked off from each
y broad barren regions. The broadest of these is nearly
e, lying between the first and second centres of activity,
th its centre about 260° of longitude. The second
region lies between the third and the first centres, and is
5° wide, with its centre of longitude 140°. The third and
est lies between the second and third centres, and is about
le, with its centre of longitude 40°. The three centres of
have their positions, the first around longitude 200°,
ond around longitude 340°, and the third around longi-
°.

diagram shows *all* the spots within the latitudes named
riod of fourteen years and three months—191 rotations
ington's period. During this interval of time a spot
with the rotation-period adopted would gain two rotations
e-third upon another moving at Carrington's rate. A
smaller value for the rotation-period, one gaining two
s and a half in the interval, would have satisfied the
tions even better.

great barren belt at longitude 260° can be traced though

a differentiation is set up which may last for even a term These regions of activity may show many changes in its ation during that time. The activity may be intermittent;)scillate from one latitude to another; it may vibrate ds and forwards in longitude; and yet its continuity may holly lost. The analogy of the Great Red Spot of *Jupiter*) us here. It has been continuously under observation y thirty years; very possibly it has existed for more than mes as long. But taking the shorter period, it has hat time varied much in colour and intensity, slightly in shape; it has been very intermittent in its distinctness; d of rotation has differed much from those of neighbour- , and has varied from one year to another. Yet it has d its individuality through all, and there is no doubt of nuity of its existence. Though it is evidently no solid)r its changes of motion preclude that idea—yet it evi- lenotes something of structure, something of specialisa- hat region of *Jupiter*. So though we cannot predicate— nly not as yet—any such long-continued specialisation regions upon the Sun, yet we think that very strong)ns have been afforded us that a certain degree of ation, though of a less permanent character, is already ss there.

rwhitt Road, St. John's, Brockley, S.E.:
1905 *March* 6.

Note on Instrumental Errors affecting Observations of foon: in reply to Mr. Cowell's Paper of 1904 *June.* By . Turner, D.Sc., F.R.S., Savilian Professor.

g to my absence in America, Mr. Cowell's paper of June not come to my notice in the ordinary course, and was l by me comparatively recently. Though I am reluctant ıg a controversy of little general interest, there are at) statements in the paper which seem to me to require ıt corrections, and I hope to indicate them as briefly as The first statement is as follows (bottom of p. 695): fessor Turner . . . has thrown aside the observations he calls 'day 15' (or full moon) and smoothed out days 16. These are the most important observations of all, the parallactic inequality is then most different from its lue, and we are at once left with an amount of material nt for its purpose."

statement is irrelevant, because I was not dealing with llactic inequality or concerned with it in any way what- was discussing *instrumental error*, the motion of the

ith all its characteristics having been eliminated by the
process of comparing observations made by one instrument
ose made by another at virtually the same moment. The
tions might have been made, for instance, on a fixed
l disc. My procedure cannot therefore be criticised from
int of view applicable in the case of the parallactic
ity.

ve pointed this out to Mr. Cowell, but he still maintains
criticism applies because my discussion of instrumental
ggested a word of caution as to the correctness of his
for the parallactic inequality. The point is rather a
than a mathematical one, and I will venture to illustrate
tention of irrelevance by an analogy.

pose Mr. Cowell to be discussing the chances of a broken
which travellers are liable, from statistics of journeys
n London and Liverpool, and that, in order to be strictly
the railways, he acknowledged that some of the accidents
have occurred at home, setting down, without indicating
arrived at it, an estimate of that number. Suppose,
, that from the history of stay-at-homes who take no
s * I arrived at the conclusion that the estimate so made
dequate ; then surely my methods for discussing stay-at-
are not to be judged by the rules applicable to travellers

because the longitude of the centre is made up of two terms—

$$\underset{\text{longitude of limb}}{P} \quad \pm \quad \underset{\text{observed semidiameter}}{Q}$$

of which P does not, and Q does, automatically change sign at full moon. Errors in longitude of the Moon naturally associate themselves with P, and were chiefly present to Mr. Cowell's mind; instrumental errors, especially the variability in observed semidiameter with approaching daylight, equally naturally associate themselves with Q, and were chiefly present to my mind (as may be seen on reference to *Monthly Notices*, vol. lxiv., bottom of p. 410). Hence it is clear that we cannot decide the applicability or non-applicability of terms such as sin D or cos D by their changing sign at full moon; we merely determine whether they are associated with P or Q.

Thus in the series suggested by me on p. 567

$$a_1 \sin D + b_1 \cos D + a_2 \sin 2D + b_2 \cos 2D + \text{ \&c.}$$

for representing instrumental error, if we are thinking of Q we should expect the part

$$C = b_1 \cos D + b_2 \cos 2D + \text{ \&c.}$$

to be large and

$$S = a_1 \sin D + a_2 \sin 2D + \text{ \&c.}$$

to be small; if we are thinking of P being affected it might be the other way. Hence I do not see that Mr. Cowell's paragraph on p. 696 (when the above possible misunderstanding is cleared away) is any answer to the remark I made on p. 568. For clearness may I recall very briefly the sequence of events?

I raised the question whether the instrumental errors of the old transit circle in use to 1851 were not sensibly different from those of the new one used afterwards.

Mr. Dyson replied (p. 566) that the coefficients of sin D, deduced by Mr. Cowell from the observations, showed no such change.

I rejoined (p. 567) that such evidence was incomplete, since terms involving cos D, cos 2D, &c., had not been included in the series, and that these had probably a very real existence for reasons given.

To this I venture to think no real response has been made either on p. 696 or otherwise. It is true that Mr. Cowell has since looked for, and found, a term $0''\cdot28 \cos D$ (p. 695, line 9) "which must be attributed to errors of observation"; but I believe this is applicable to longitude (called P above) and not to semidiameter (Q above). It seems to me, in the light of our recent discussion, that a complete investigation would contemplate *four* sets of terms: viz. (1) sines applicable to P, (2) sines

applicable to Q, (3) cosines applicable to P, (4) cosines applicable to Q. But in practice it would be doubtless impossible to separate these terms satisfactorily.

Before leaving the point perhaps I may state my position in other words thus:

Mr. Cowell writes (vol. lxiv. p. 96): "The hypothesis that the error of semidiameter is a constant is the best that I can make."

I venture to doubt this, even in the circumstances considered by Mr. Cowell. I think he should have considered the expression

$$b_0 + b_1 \cos D + b_2 \cos 2D + \&c.$$

instead of the first term only.

The remainder of Mr. Cowell's paper is an admirable exposition of the principles of his analysis, which I am glad to have drawn from him. If I refrain from comment it is because I am afraid of prolonging the discussion unduly. The two points mentioned seem to me important, and I hope I have made my position with regard to them clear. Mr. Cowell and I have, as already mentioned, discussed these matters without being able to arrive at an agreement, so that he will doubtless represent his views clearly also, and there I hope the matter may be left.

Reply to Professor Turner's further Note. By P. H. Cowell.

1. Let me put

N = instrumental error of transit circle (1851–61)
O = " " "old transit circle" (1847–50)
L = " " altazimuth (1851–61)
M = " " " (1847–50)

Then Professor Turner has shown, by processes that I have no objection to, that N—O—L+M varies from $0''\cdot0$ on day 17 to $+1''\cdot3$ on day 21, and then decreases to $+0''\cdot8$ on day 24, the zero being an arbitrary one (vol. lxiv. p. 411).

Regarding this table merely as proving that the above combination of instrumental error varies with the day of the lunation, it was clearly unnecessary for me to call attention to the absence of days 15 and 16. The importance of these days is, however, considerable when we attempt to consider the law connecting the above observed quantity with the age of the Moon.

I do not wish my chief objections to Professor Turner's first paper to be obscured by a discussion of minor points. What I object to is this. He says L—M may be put equal to zero, and

he puts N—O instead of N—O—L+M at the top of the table referred to. From some analyses of my own, given on vol. lxiv. p. 580, it may be inferred that the values of N—O are really about one-third of those given by Professor Turner. The other two-thirds must apparently be ascribed to L—M, and give some indication of the accidental errors to which the altazimuth was liable.

2. The formula to which I equate the errors is

$$\begin{aligned}\epsilon \pm \mu + \delta_1 \sin D + \delta_2 \sin 2D + \ldots \\ + \Delta_1 \cos D + \Delta_2 \cos 2D + \ldots\end{aligned}$$

The formula used by Airy (*Memoirs* R.A.S., vol. xxix. p. 4) is

$$\delta_1 \sin D + \delta_2 \sin 2D$$

Professor Turner suggests

$$\begin{aligned}&\pm(\mu + b_1 \cos D + b_2 \cos 2D + \ldots \\ &\qquad + a_1 \sin D + a_2 \sin 2D + \ldots) \\ &+ \epsilon + \delta_1 \sin D + \delta_2 \sin 2D + \ldots \\ &+ \quad \Delta_1 \cos D + \Delta_2 \cos 2D + \ldots\end{aligned}$$

My formula is therefore intermediate between that used by Airy and that suggested by Professor Turner.

There is a phrase, "necessary and sufficient," in constant use by mathematicians. I maintain that Airy's formula is insufficient and Professor Turner's unnecessary. Airy's is insufficient because the deduced value of the parallactic inequality is clearly erroneous if his semidiameter is erroneous. Airy has, in effect, therefore made his parallactic inequality depend, not upon the 10,000 observations that he reduced, but upon the 100 observations that he used for semidiameter.

Each one of the additional terms proposed by Professor Turner can, on the other hand, be shown to be unnecessary. I will take one only as an example, $\pm b_1 \cos D$. This may be replaced by

$$b_1(\pm 1{\cdot}000 - 1{\cdot}056 \sin D + 0{\cdot}478 \sin 2D)$$

for the expression that I have just written down differs from $\pm b_1 \cos D$ by considerably less than $\frac{1}{10} b_1$ from $D = 70°$ to $D = 290°$.

A similar remark being true of all Professor Turner's other terms as well, it is clear that he adds nothing to the generality of my hypothesis by assuming that the semidiameter is

$$\begin{aligned}\mu + b_1 \cos D + b_2 \cos 2D \\ + a_1 \sin D + a_2 \sin 2D\end{aligned}$$

han by assuming that it is

$$\mu \pm (\alpha_1 \sin D + \alpha_2 \sin 2D + \beta_1 \cos D + \beta_2 \cos 2D)$$

h case the inequalities of semidiameter merge into the ities of longitude.

point can also be demonstrated thus. Remove $\pm\mu$ from nula, and it becomes the most general expression possible rs periodic in the lunation and free from discontinuity. per provision to make for a single discontinuity is to ce a single additional unknown quantity.

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oefficient of the Principal Term in the Moon's Latitude.
By P. H. Cowell.

he coefficient of sin F in Hansen's latitude transformed to Delaunay's ... ... 18461″·65

he mean value of the observed *minus*

Point Distributions on a Sphere, with some Remarks on termination of the Apex of the Sun's Motion. By H. C. ner, M.A.

several astronomical problems we have to consider the on on a sphere of a large number of points which do r to be scattered uniformly, but, on the contrary, reveal y, more or less pronounced, towards some great circle here. An obvious instance is the distribution of the ie sky, and the question has been discussed from this iew by Professor Newcomb in his recent paper "On the of the Galactic and other Principal Planes toward which tend to crowd." * The determination of the position of reat circle or "plane of condensation" is required in mexions, the instance quoted being the simplest and nite illustration.

tars are represented by n points on a sphere of unit They are supposed to be crowded in the vicinity of a eat circle, but the divergences cannot be regarded in s small, and the law of crowding is unknown. Under umstances it is necessary to define the plane of conden- id Professor Newcomb defines it as the plane of that le for which the sum of the squares of the sines of the of all the stars is a minimum. In other words, if v is ice of any star from the pole of the great circle, the condensation is such that

$$\Sigma \cos^2 v \text{ is a minimum}$$

coordinate system of rectangular axes $O\xi\eta\zeta$ be taken itre of the sphere, $O\xi$ passing through the pole of the circle. Then the preceding condition becomes

$$\Sigma\xi^2 \text{ is a minimum}$$

$$\xi^2+\eta^2+\zeta^2=1$$

$$\Sigma(\eta^2+\zeta^2) \text{ is a maximum}$$

ve assign unit mass to each of the points on the sphere, tion in its last form shows that the moment of inertia stem about $O\xi$ is the greatest possible. Hence the s reduced simply to that of finding one of the principal iertia for the system of loaded points on the sphere.

any system of rectangular axes $Oxyz$ (*e.g.* the equatorial et (a, b, c) be the coordinates of any one of the stars,

$$\Sigma a^2,\ B = \Sigma b^2,\ C = \Sigma c^2,\ F = \Sigma bc,\ G = \Sigma ca,\ H = \Sigma ab$$

ibutions to Stellar Statistics. First Paper. Washington (1904).

omental ellipsoid can be written

$$C)x^2+(C+A)y^2+(A+B)z^2-2Fyz-2Gzx-2Hxy=1$$

can be transformed by a change of axes to *

$$\mu_1\xi^2+\mu_2\eta^2+\mu_3\zeta^2=1$$

(μ_1, μ_2, μ_3) are the roots of the equation

$$\begin{vmatrix} B+C-\mu & -H & -G \\ -H & C+A-\mu & -F \\ -G & -F & A+B-\mu \end{vmatrix} = 0$$

Oξ is the axis required if μ_1 is the greatest root of this on.

s result differs in form from that found by Professor mb, but the latter can be deduced immediately. For let

$$\lambda+\mu = A+B+C$$

he value of λ corresponding to μ_1 is clearly the smallest the equation

$$\begin{vmatrix} A-\lambda & H & G \end{vmatrix} = 0$$

Professor Harzer,* who has recently added some developments of the theory. In this problem the points which possess a zone of condensation are the poles of the great circles along which the observed proper motions take place. If then the plane of condensation can be determined by the method thus described, the apex of the solar motion is found as the pole of this plane. When different weights are assigned to the poles of the proper motions, these are to be used in finding the momental ellipsoid.

This method, at first sight so simple and elegant, is not free from difficulty and has been criticised in particular by M. Radau.† The difficulty is due to the absence of distinction between those poles which correspond to direct proper motions (with components directed towards the antiapex) and those which correspond to retrograde proper motions (with components directed towards the apex). If the position of the apex were known the two classes of poles could be discussed separately, and from the two results a weighted combination could be deduced which would represent the resultant of evidence in itself contradictory. Since the position of the apex, so far from being known, is precisely what has to be determined, the distinction between the two classes cannot be drawn directly, and we are reduced to the necessity of making a series of successive approximations. This method, though laborious, seems perfectly feasible.

In using the general method Dr. Kobold ignored the distinction between direct and retrograde proper motions. This procedure is equivalent to reversing the proper motions of those stars whose motion is retrograde. His result as regards the declination of the apex is in marked disagreement with the results found by other astronomers who used other methods, for it places the apex practically on the equator. By taking averages for stars in the same region of the sky instead of treating the proper motions separately, he obtained a result in better accord with other determinations. Hence it has been concluded that the discrepancy is to be attributed to the faulty nature of the method employed by Dr. Kobold. The whole question of the method which ought to be used for the determination of the apex of the solar motion has been the subject of much controversy, into which it is not intended to enter. But the discrepancy presented by Dr. Kobold's results cannot be passed over without some further consideration.

The axiom which lies at the base of all determinations of the apex is that the intrinsic proper motions of the stars exhibit no particular directed tendency, but possess in the main the character of errors of observation. If this be true, a simple consequence follows which is easily expressed in terms of the dynamical analogy employed in § 1. For it is evident that if we find the

* *Astr. Nachr.*, Nos. 3173 and 3998; also W. T. Carrigan, *Astr. Journ.*, No. 565.

† *Bull. Astr.*, vol. x. p. 401.

al ellipsoids for (1) the direct proper motions, (2) the
de proper motions, (3) all proper motions irrespective of
hen (1) and (2) ought to be ellipsoids of revolution of
he axes of symmetry should be directed to the apex of the
otion. If this be the case the axis of (3), which corre-
to Dr. Kobold's procedure, will be at least a near approxi-
to the true solution of the problem. If it be not the case
psoids (1) and (2) are either not surfaces of revolution or
es are not coincident, the latter being the form to which
au reduces his criticism of the method. Now either of
ppositions directly refutes the fundamental axiom. Hence
lusion seems to be that if the material on which the dis-
is based were perfectly satisfactory, even the method
by Dr. Kobold would be a proper one. That it leads to
icuous discrepancy with the results of other methods sug-
rongly that the difficulty should be located not so much
merits or demerits of a particular method as in the
f the proper motions employed. And Professor Harzer *
from some unpublished figures communicated by
bold that the errors are not all accidental.

ming that there is strong evidence that the intrinsic
notions deviate in a marked degree from a purely acci-
haracter, we have to inquire whether the deviations are

ı proper motions as in the *Pleiades*. But such groups) only particular cases of a feature characterising all motions and destructive of any uniform hypothesis.

his view is correct, the physical significance of what is as the motion of the Sun in space is greatly modified, for ity relative to two or more streams has no meaning. A xtension of optical theory and experiment may reveal the of the Sun relative to the ether, but this would have no ; on the present question. The direction of the motion as ined by statistical methods can have merely a statistical g, and the agreement between the results of different ls is due to the fact that the methods are statistically ent. And since determinations of the constant of pre- are affected by the corrections adopted for the parallactic s, this constant also cannot be regarded as that which corresponds to the dynamical conditions from which as a ıl quantity it results.

A third problem which can be solved by the use of the general method is that of the determination of meteor s. The radiant of the *Leonids* in 1899 was found in this r Dr. Kobold.* In this application there is, of course, no ifficulty as occurs in the determination of the solar apex.

ɜ object of this note has been to point out the interpreta- a method originally due to Bessel in terms of a momental id, and the application of this single principle to three t problems : (1) the distribution of stars possessing a zone centration, (2) the determination of the apex of the Sun's ı, and (3) the determination of meteor radiants. The lant result found on applying the method to the second n necessitated a digression in which the cause of the ıancy has been briefly discussed. It is concluded that s a pronounced departure from an accidental distribution intrinsic proper motions of the stars, and it is suggested re have to deal with two or more independent streams which the relative motions may be distributed more or accordance with the normal law of errors.

versity Observatory, Oxford :
1905 *April* 7.

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* *Astr. Nachr.*, No. 3608, p. 120.

sion of the Observations of the Satellite of Neptune made at Royal Observatory, Greenwich, in the years 1902-3-4. F. W. Dyson, M.A., F.R.S., and D. J. R. Edney.

e observations discussed in this paper are published in the *ly Notices*, vols. lxii., lxiii., and lxiv., and are obtained hotographs with the 26-inch refractor taken with the aid occulting shutter. Specimen photographs are given in *ly Notices*, vol. lxii. p. 623, with an account of the occulting r and method and details of measurement. The published res are compared with tabular places obtained from *onnaissance des Temps* based on Mr. Hermann Struve's ts.

e notation and formulæ employed in obtaining corrections elements are taken from Mr. Struve's discussion in the *res de l'Académie Impériale des Sciences de St.-Pétersbourg*, rie, tome xlii., No. 4. As Mr. Struve has discussed the ations prior to 1892, and as his elements are employed in *nnaissance des Temps*, it is desirable and convenient to losely to his form. The only difference in notation is that, ng the *Connaissance*, +U is written where Mr. Struve

The formulæ for correcting the elements are given by
. H. Struve in the form

$$
\begin{aligned}
s \sin dp = {} & r \sin \tau \,.\, \sin du \\
& + (r \sin \tau \cos \mathrm{I} + r \cos \tau \cos u \sin \mathrm{I}) \,.\, \sin d\mathrm{N} \\
& - r \cos \tau \sin u \,.\, \sin d\mathrm{I} \\
& - r \sin \tau \cos u \,.\, 2e \sin \mathrm{Q} \\
& + r \sin \tau \sin u \,.\, 2e \cos \mathrm{Q}\ ; \\
ds = {} & r \cos \sigma \cos \tau \,.\, \sin du \\
& + r \cos \sigma \sin p \cos \delta \,.\, \sin d\mathrm{N} \\
& + r \cos \sigma \sin \tau \sin u \,.\, \sin d\mathrm{I} \\
& - \left(r \cos \sigma \cos \tau \cos u + \frac{s}{2} \sin u \right) . \ 2e \sin \mathrm{Q} \\
& + \left(r \cos \sigma \cos \tau \sin u - \frac{s}{2} \cos u \right) . \ 2e \cos \mathrm{Q} \\
& + s \,.\, \frac{da}{a}
\end{aligned}
$$

ere e is the eccentricity, and Q the longitude of periastron
asured from the node of the satellite's orbit on the Earth's
ator.

And the auxiliaries τ and σ are defined by the equations :

$$
\begin{aligned}
\sin \tau &= \frac{r}{s} \sin \mathrm{B} \\
\cos \tau &= \frac{r}{s} \cos \mathrm{B} \sin (u + \mathrm{U}) \\
\cos \sigma &= \cos \mathrm{B} \cos (u + \mathrm{U}).
\end{aligned}
$$

adopted value of N and I in the above formulæ are

$$
\begin{aligned}
\mathrm{N} &= 185^\circ{\cdot}15 + 0^\circ{\cdot}148\ (t - 1890) \\
\mathrm{I} &= 119{\cdot}35 - 0{\cdot}165\ (t - 1890)
\end{aligned}
$$

equations of condition obtained by applying the above
nulæ to the results of the Greenwich photographs are given
ow for the three oppositions considered. The residuals are
en in the last column. Taking $e = 0$ and adopting the mean
ues for du, dN, dI, and $\frac{da}{a}$, the probable error for weight 1,
for a result derived from one photograph, is $\pm 0''{\cdot}14$ for both
distances and position-angles.

Equations of Condition.

Position-angle.

Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.		s sin dp.	Residual.
	″	″	″	″	″		″	″
2	−14·1	+1·0	−6·9	− 9·5	−10·5	=	+0·18	−0·05
2	−15·9	+6·7	+5·6	− 2·2	+15·8	=	+ ·21	+ ·01
2	−12·5	−2·8	−5·9	−10·7	− 6·5	=	+ ·35	+ ·11
2	−11·8	−2·7	+7·9	+ 8·9	− 7·7	=	+ ·29	+ ·10
2	−16·8	+7·8	+0·3	− 2·6	−16·6	=	+ ·36	+ ·14
1	−11·9	−4·2	−4·9	−10·8	− 4·9	=	+ ·39	+ ·15
1	−11·5	−3·7	+6·9	− 9·5	+ 6·4	=	·00	− ·21
2	−16·4	+6·6	−3·0	− 5·4	−15·5	=	+ ·21	− ·02
4	−11·2	−5·6	−2·7	−10·9	− 2·5	=	+ ·20	− ·03
1	−12·2	−1·1	+8·6	− 8·1	+ 9·1	=	+ ·14	− ·05
1	−16·3	+6·3	−3·4	+ 5·7	+15·2	=	+ ·36	+ ·13
2	−12·6	+0·1	+8·8	+ 7·4	−10·2	=	+ ·13	− ·06
2	−16·1	+5·9	−4·1	− 6·3	−14·8	=	+ ·44	+ ·20
3	−14·0	+1·5	−6·6	− 9·2	−10·7	=	·00	− ·23
1	−10·6	−6·2	+2·5	−10·4	+ 2·1	=	+ ·52	+ ·12

ate.	Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.	$\frac{da}{a}$.		s sin dp.	Residual.
902.		″	″	″	″	″	″		″	″
b. 11	4	+3·7	−4·5	− 0·7	+1·8	+8·6	+16·0	=	+ ·03	−·02
12	1	−5·5	+5·9	− 4·4	+1·8	+9·0	+14·6	=	− ·11	−·25
13	1	+2·8	−5·1	−11·5	+4·2	−4·5	+10·9	=	+ ·28	+·21
15	2	−5·8	+6·2	− 5·5	−2·3	−8·9	+14·1	=	+ ·22	+·09
16	2	+3·3	−5·7	−11·1	−3·8	+5·2	+11·1	=	+ ·07	·00
28	3	+5·7	−8·1	− 7·1	−1·0	+8·4	+12·4	=	+ ·17	+·12
r. 1	1	−0·2	+0·2	0·0	+1·4	+8·3	+16·6	=	+ ·15	+·06
3	5	+5·9	−8·1	− 6·3	+0·5	−8·6	+12·7	=	+ ·03	−·01
17	1	−1·4	−0·2	−12·5	−5·4	−0·9	+10·5	=	− ·17	−·28
19	3	−3·7	+4·2	− 1·8	+1·2	+8·5	+15·6	=	+ ·21	+·10
21	3	+4·9	−6·2	− 1·9	−1·6	−8·8	+14·8	=	+ ·10	+·05
22	1	−4·6	+5·1	− 2·8	−1·4	−8·7	+15·1	=	+ ·23	+·10
25	3	−4·6	+5·1	− 2·9	+1·4	+8·7	+15·0	=	+ ·06	−·07
27	4	+4·0	−5·0	− 1·0	−1·8	−8·5	+15·4	=	− ·06	−·11
r. 6	1	−5·7	+6·1	− 5·6	+2·3	+8·6	+13·6	=	+ ·24	+·12
10	2	+4·7	−7·1	− 9·1	−2·4	+6·9	+11·3	=	+ ·22	+·17

Equations of Condition.

Position-angle.

Date.	Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.		s sin dp.	Residual.
1902.		″	″	″	″	″		″	″
Nov. 12	4	−12·5	−1·3	+7·9	+ 8·9	− 8·8	=	−0·15	−·27
13	2	−16·5	+6·9	−3·0	− 3·8	−16·1	=	− ·19	−·35
17	1	−11·2	−5·8	−2·7	+10·9	+ 2·4	=	+ ·49	+·31
28	2	−14·7	+2·6	−6·9	+ 8·1	+12·5	=	− ·04	−·23
Dec. 29	2	−11·6	−4·1	+6·4	+ 9·9	− 6·0	=	− ·13	−·26
31	2	−11·6	−5·1	−4·1	−10·9	− 3·9	=	+ ·06	−·13
1903. Jan. 1	1	−12·7	−0·9	+8·3	− 8·6	+ 9·4	=	− ·03	−·14
3	2	−11·5	−5·2	−3·9	+10·9	+ 3·7	=	+ ·64	+·45
15	3	−11·0	−6·4	−0·3	+11·0	+ 0·3	=	+ ·28	+·11
23	3	−14·5	+2·0	−6·9	− 8·7	−11·6	=	+ ·50	+·30
25	1	−14·6	÷3·9	+7·7	− 5·5	+13·6	=	− ·28	−·38
28	2	−14·7	+4·1	+7·6	+ 5·3	−13·7	=	+ ·29	+·19
Feb. 1	1	−13·2	−0·8	−6·9	+ 9·9	+ 8·8	=	+ ·77	+·58
2	1	−10·9	−6·0	+3·4	+10·5	− 2·9	=	+ ·22	+·07
6	1	−16·1	+6·9	+4·6	− 2·0	+16·0	=	+ ·61	+·49
10	1	−12·3	−3·1	−5·9	−10·5	− 6·4	=	+ ·07	−·12
16	2	−11·4	−5·2	−3·7	−10·8	− 3·5	=	+ ·19	·00
17	3	−11·5	−3·6	+6·8	− 9·5	+ 6·5	=	− ·05	−·17

Weight.	sin *du*.	sin *d*N.	sin *d*I.	2*e* sin Q.	2*e* cos Q.	*s* sin *dp*.	Residual
	″	″	″	″	″	″	″
3	−16·7	+7·4	−1·3	+ 3·2	+16·4 =	+ ·15	·00
1	−11·8	−2·6	+7·6	− 9·0	+ 7·6 =	+ ·27	+·15
1	−12·2	−1·4	+8·1	+ 8·5	− 8·8 =	+ ·21	+·10
3	−10·9	−5·9	−2·0	−10·8	− 1·7 =	+ ·29	+·11
3	−10·9	−6·0	−1·6	+10·8	+ 1·4 =	− ·03	−·21
3	−10·7	−6·3	−0·3	−10·7	− 0·3 =	+ ·22	+·06
2	−14·6	+2·9	−6·4	− 8·1	−12·1 =	·00	−·18
1	−13·9	+3·1	+8·0	− 5·9	+12·7 =	+ ·12	+·02
2	−10·6	−6·0	+2·0	+10·5	− 1·6 =	+ ·23	+·08
2	−14·9	+5·2	+6·7	+ 4·0	−14·4 =	·00	−·10
2	−10·7	−5·8	+3·5	+10·2	− 3·0 =	− ·11	−·25
1	−12·4	−2·0	−6·3	+10·0	+ 7·3 =	+ ·36	+·18
1	−11·8	−3·7	+7·7	+ 8·4	− 8·2 =	+ ·47	+·34
1	−10·8	−5·5	−2·6	−10·5	− 2·4 =	+ ·51	+·33
1	−12·1	−0·7	+8·0	− 8·0	+ 9·1 =	− ·04	−·14
1	−14·8	+4·0	−5·7	+ 7·0	+13·0 =	+ ·18	+·01
1	−14·3	+3·1	−6·2	− 7·6	−12·1 =	+ ·22	+·04

Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.	$\frac{da}{a}$.		s sin dp.	Residual.
	$''$	$''$	$''$	$''$	$''$	$''$		$''$	$''$
3	−4·2	+4·9	− 2·3	+0·9	+8·8	+15·6	=	+ ·20	+·08
3	+1·0	−2·6	−12·5	+5·1	−2·0	+10·8	=	− ·01	−·14
1	−4·9	+5·6	− 3·2	+1·2	+8·9	+15·1	=	− ·02	−·14
1	−5·4	+6·1	− 4·2	−1·5	−9·0	+14·6	=	+ ·16	+·04
3	+2·7	−3·3	− 0·4	+1·4	+8·4	+16·2	=	+ ·30	+·22
3	+2·4	−3·0	− 0·3	−1·4	−8·4	+16·2	=	+ ·10	+·02
3	+1·5	−1·8	0·0	+1·3	+8·3	+16·4	=	+ ·19	+·11
2	+5·3	−7·4	− 8·3	−2·1	+7·7	+12·0	=	+ ·27	+·17
1	−5·7	+6·0	− 8·2	+3·3	+7·8	+12·6	=	+ ·21	+·07
2	−0·3	+0·3	0·0	−1·0	−8·2	+16·4	=	+ ·18	+·09
2	−4·9	+4·7	−10·1	−4·3	−6·3	+11·7	=	− ·15	−·30
2	−1·5	+1·8	− 0·4	−0·9	−8·2	+16·3	=	+ ·56	+·46
1	+5·6	−7·3	− 3·9	−0·4	−8·9	+13·9	=	+ ·16	+·07
1	−5·1	+5·8	− 3·8	−1·3	−8·7	+14·3	=	− ·04	−·16
1	+3·1	−3·8	− 0·6	+1·3	+8·3	+15·6	=	− ·02	−·10
1	−5·4	+6·1	− 4·7	+1·7	+8·7	+13·9	=	− ·15	−·27
1	+4·6	−6·5	− 9·2	+2·8	−6·7	+11·3	=	− ·01	−·11
1	+5·0	−7·0	− 8·4	−2·3	+7·4	+11·6	=	− ·17	−·26

Equations of Condition.

Position-angle.

e.	Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.		s sin dp.	Residual.
l.		$''$	$''$	$''$	$''$	$''$		$''$	$''$
4	1	−11·2	−5·9	−2·8	+10·9	+ 2·4	=	+0·13	−·11
8	1	−13·9	+1·4	+7·9	− 7·8	+11·4	=	+ ·26	+·11
9	2	−15·4	+4·4	−6·3	+ 6·5	+14·0	=	+ ·25	+·07
10	2	−11·1	−6·4	−1·1	+11·0	+ 0·9	=	+ ·33	+·09
14	1	−14·2	+2·1	+7·9	− 7·4	+12·1	=	+ ·11	−·04
15	1	−14·6	+2·6	−7·2	+ 7·8	+12·4	=	+ ·29	+·08
17	1	−14·5	+2·9	+7·7	+ 6·9	−12·7	=	+ ·05	−·09
30	2	−12·8	−1·8	−7·0	− 9·9	− 8·1	=	+ ·22	−·01
31	2	−11·4	−5·2	+4·6	−10·6	+ 4·2	=	+ ·29	+·07
l. 6	1	−11·6	−4·4	+5·7	−10·3	+ 5·4	=	+ ·26	+·05
13	2	−16·9	+7·7	+0·3	+ 0·7	+16·9	=	+ ·23	+·08
14	2	−11·7	−4·6	−4·9	+10·8	+ 4·7	=	+ ·27	+·02
15	3	−12·2	−2·7	+7·2	+ 9·6	− 7·5	=	+ ·26	+·08
19	2	−16·6	+7·0	−2·9	+ 3·6	+16·2	=	+ ·15	−·01
22	1	−16·7	+7·2	−2·3	− 3·1	−16·4	=	+ ·16	·00
2	1	−14·0	+2·0	+8·0	+ 7·2	−12·0	=	− ·23	−·37

Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.		s sin dp.	Residual.
4	$-14''.2$	$+2''.7$	$+7''.9$	$-6''.8$	$+12''.5$	=	$+''.13$	$-''.02$
1	-14.6	$+2.6$	-6.9	$+8.0$	$+12.2$	=	$+.07$	$-.13$
2	-10.9	-6.3	$+1.8$	$+10.8$	-1.6	=	$+.18$	$-.05$
2	-13.4	-0.2	-7.2	-9.4	-9.5	=	$+.30$	$+.07$
2	-15.8	$+6.1$	$+5.3$	-3.5	$+15.4$	=	$+.05$	$-.08$
2	-11.3	-5.1	-3.9	-10.6	-3.7	=	$+.13$	$-.10$
4	-12.3	-1.5	$+7.7$	-8.8	$+8.6$	=	$+.19$	$+.02$
2	-14.8	$+3.7$	-6.2	-7.1	-13.0	=	$+.31$	$+.12$
2	-10.7	-5.7	$+3.2$	$+10.3$	-2.8	=	$+.26$	$+.04$
1	-10.8	-5.0	$+4.6$	$+10.0$	-4.1	=	$+.34$	$+.14$
2	-16.0	$+7.2$	$+1.8$	-0.4	$+16.0$	=	$+.16$	$+.03$
2	-11.2	-3.8	$+6.1$	$+9.5$	-5.8	=	-0.02	$-.21$

Equations of Condition.

Distance.

ight. sin du. sin dN. sin dI. $2e$ sin Q. $2e$ cos Q. $\frac{da}{a}$. s sin dp. Resi-dual.

Date.	Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.	$\frac{da}{a}$.		s sin dp.	Residual.
1903.		"	"	"	"	"	"		"	"
Mar. 10	2	+3·7	−4·6	− 1·1	+0·9	+8·6	+15·7	=	+ ·06	+ ·02
11	4	−5·4	+6·2	− 4·2	+1·2	+8·9	+14·4	=	− ·09	− ·13
21	2	+4·9	−6·6	− 9·0	−2·8	+7·1	+11·8	=	+ ·24	+ ·18
Apr. 6	2	−1·7	+2·1	− 0·4	−0·4	−8·2	+16·1	=	+ ·36	+ ·34
12	1	−2·8	+3·4	− 1·0	−0·4	−8·4	+15·7	=	+ ·26	+ ·23
16	2	−1·4	+0·9	−12·1	+5·3	+1·5	+10·6	=	+ ·09	+ ·02
18	2	−4·0	+4·8	− 2·0	−0·5	−8·6	+15·1	=	+ ·22	+ ·18

Normal Equations.

1902.

	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.	$\frac{da}{a}$.		
sin du	9927	−1504	+ 96	+1131	+1189	+ 930	=	−148·14
sin dN		2684	+ 687	+ 139	− 660	−1602	=	− 4·44
sin dI			3935	+ 141	+ 120	−3295	=	− 31·88
$2e$ sin Q				4241	+1516	− 169	=	− 19·34
$2e$ cos Q					8059	+1260	=	− 15·47
$\frac{da}{a}$						9526	=	+ 53·08

1902–03.

	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.	$\frac{da}{a}$.		
sin du	11430	− 673	− 400	− 406	+1106	+ 222	=	−123·09
sin dN		3060	+ 158	− 280	− 301	− 618	=	− 18·17
sin dI			4120	+ 528	− 69	− 3471	=	− 36·90
$2e$ sin Q				5479	+ 628	− 86	=	+ 7·39
$2e$ cos Q					9307	− 590	=	+ 1·77
$\frac{da}{a}$						13333	=	+ 93·48

1903–4.

	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.	$\frac{da}{a}$.		
sin du	10146	−1547	− 710	− 108	−2758	− 581	=	−127·67
sin dN		2468	− 175	− 334	+1233	+ 496	=	− 5·87
sin dI			4232	− 715	+ 230	− 3579	=	− 8·18
$2e$ sin Q				3956	− 210	+ 563	=	+ 2·70
$2e$ cos Q					8714	− 12	=	+ 26·23
$\frac{da}{a}$						10074	=	+ 34·39

Solutions.

1902.	1902–3.	1903–4.	Mean.
−0·01653	−0·01160	−0·01458	−0·0142
−0·00736	−0·00688	−0·01250	−0·0089
−0·00196	−0·00512	−0·00349	−0·0035
+0·00051	+0·00053	−0·00167	−0·0002
−0·00039	+0·00163	+0·00022	+0·0005
+0·00533	+0·00563	+0·00201	+0·0043
−0°·95	−0°·67	−0°·83	−0°·82
−0·42	−0·40	−0·72	−0·50
−0·12	−0·30	−0·20	−0·20
+0″·087	+0″·092	+0″·033	+0″·070

Eccentricity of the Orbit.—The three determinations
at the eccentricity is extremely small, the value actually
r $2e \sin Q$ and $2e \cos Q$ being smaller than their probable
Mr. H. Struve gave ·01 as the maximum possible value
eccentricity. The present observations show the limit

Rejecting the terms $2e \sin Q$ and $2e \cos Q$ and combining the three series of normal equations we obtain

	$\sin du.$	$\sin dN.$	$\sin dI.$	$\frac{da}{a}.$	
$\sin du$	31503	-3724	$-\ 1014$	$+\ 571$	$=-398{\cdot}90$
$\sin dN$		$+8212$	$+\ 670$	$-\ 1724$	$=-\ 28{\cdot}48$
$\sin dI$			$+12287$	-10345	$=-\ 76{\cdot}96$
$\frac{da}{a}$				$+32933$	$=+180{\cdot}95$

These equations give for the epoch 1903·1 :

$$\sin du = -{\cdot}0139 \pm {\cdot}00081 \quad du = -0^{\circ}{\cdot}80 \pm {}^{\circ}{\cdot}08$$
$$\sin dN = -{\cdot}0086 \pm {\cdot}00193 \quad dN = -0^{\circ}{\cdot}50 \pm {\cdot}11 \quad N = 187^{\circ}{\cdot}58$$
$$\sin dI = -{\cdot}0034 \pm {\cdot}00128 \quad dI = -0^{\circ}{\cdot}20 \pm {\cdot}07 \quad I = 117^{\circ}{\cdot}40$$
$$\frac{da}{a} = +{\cdot}0042 \pm {\cdot}00093 \quad da = +0''{\cdot}069 \pm ''{\cdot}015 \quad a = 16''{\cdot}202$$

The Longitude and Mean Motion.—Comparison of the value $du = -0^{\circ}{\cdot}80$ with the values given for different epochs in Dr. Struve's *Memoir* (p. 61) gives a small correction to the longitude for 1890 and to the mean daily motion. The adopted values for 1890·0 $u = 234^{\circ}{\cdot}42$ and mean daily motion $n = 61^{\circ}{\cdot}25748$ appear to require corrections of approximately $-0^{\circ}{\cdot}20$ and $+0^{\circ}{\cdot}00008$ respectively.

The Mean Distance of the Satellite and Mass of Neptune.—Owing to the great difference in magnitude of *Neptune* and its satellite it is possible that the visual measures are all affected by a small personal equation. The photographic determination is free from this difficulty; and as great care was taken in the determination of the value of the scale, the photographic results would seem specially valuable for this element.

The value found, $a = 16''{\cdot}202$, corresponds to the mean distance of the planet for which $\log \rho = 1{\cdot}47814$. The corresponding value of the mass of *Neptune* is $\frac{1}{M} = 19474$.

The following values were obtained by different observers with the Washington refractor and by Dr. Struve at Pulkowa :

Newcomb	$a = 16''{\cdot}275$	$\frac{1}{M} = 19382$
Holden	16·598	18273
Hall 1875–77	16·482	18662
Hall 1881–82	16·368	19054
Hall 1883–84	16·263	19425
A. Hall (junior)	16·602	18260
H. Struve	16·271	19396
Greenwich...	16·202	19474

Movement of the Plane of the Satellite's Orbit.—The
$'N = -0^\circ{\cdot}50$, $dI = -0^\circ{\cdot}20$, give for the epoch 1903·1
$^\circ{\cdot}58$, $I = 117^\circ{\cdot}40$. The following table obtained by
he simple means of the results of different observations
same epochs in a fuller table given by Dr. Struve shows
ges in the node and inclination since the discovery of
lite :

.	N.	I.	Epoch.	N.	I.
9	179°·12	126°·01	1883·0	184°·36	120°·08
o	181·49	124·20	1890·4	185·27	119·16
8	183·10	121·46	1903·1	187·58	117·40

e changes first pointed out by Marth were explained by
d and Newcomb as arising from the spheroidal shape of
. In consequence of the spheroidal figure the orbit will
a constant inclination to the equator of *Neptune*, and the
l revolve uniformly on *Neptune's* equator ; or in other words
of the orbit will describe uniformly a small circle round the
the planet. The interesting problem is thus presented of
ning the direction of *Neptune's* axis, the inclination of

The differential relations between θ, ψ, γ, and N, I, the node and inclination, are given by the equations

$$\left.\begin{aligned} \sin\gamma d\theta &= -\cos\psi \sin \mathrm{I} d\mathrm{N} + \sin\psi d\mathrm{I} \\ d\gamma &= -\sin\psi \sin \mathrm{I} d\mathrm{N} - \cos\psi d\mathrm{I} \end{aligned}\right\}$$

Putting $\dfrac{d\gamma}{dt} = 0$ and $\dfrac{d\theta}{dt} = \text{const.}$

we obtain $\tan\psi = -\dfrac{d\mathrm{I}}{\sin \mathrm{I} d\mathrm{N}}$

In this way Dr. Struve finds for the epoch 1874·0, $\psi_1 = 52^\circ{\cdot}6$ and $\sin\gamma d\theta = 0^\circ{\cdot}208$, giving the period of revolution of the pole of the orbit round the pole of *Neptune* equal to 1734 sin γ years.

Comparing the present observations with Dr. Struve's in 1890, the changes of N and I in this interval and the value of ψ for the mean date 1896·5 is found :

(H. Struve)	1890·0	$\mathrm{N} = 185^\circ{\cdot}15$	$\mathrm{I} = 119^\circ{\cdot}35$
Greenwich	1903·1	$\mathrm{N} = 187{\cdot}58$	$\mathrm{I} = 117{\cdot}40$
	1896·5	$d\mathrm{N} : d\mathrm{I} = 2^\circ{\cdot}43 :$	$1^\circ{\cdot}95$
		$\mathrm{N} = 186^\circ{\cdot}36$.	$\mathrm{I} = 118{\cdot}38$

Therefore $\psi_2 = 41^\circ{\cdot}7$ and $\sin\gamma d\theta = 0^\circ{\cdot}224$ and the time of revolution = 1607 sin γ years.

Comparison of the values of ψ for 1874·0 and 1896·5 may be used to determine a rough value of γ, and of the position of *Neptune's* equator.

We have $\mathrm{N_1M_1} = 52^\circ{\cdot}6$ $\quad \mathrm{N_2M_2} = 41^\circ{\cdot}3 \pm 2^\circ{\cdot}5$

$\mathrm{M_1N_1N_2} = 121{\cdot}91$ $\quad \mathrm{M_2N_2N_1} = 61{\cdot}62$

and $\mathrm{N_1N_2} = 3^\circ{\cdot}40$

Solving the triangles we find

$$\mathrm{EM_2N_2} = \gamma = 22^\circ$$
$$\mathrm{M_2EN_2} = 46^\circ$$

and $$\mathrm{N_2E} = 21^\circ$$

Thus the inclination of the orbit to that of *Neptune* is 22°, and the longitude of the node and inclination of *Neptune's* to the Earth's equator are 207° and 134°.

This value of the inclination implies a rotation of the pole of the satellite's orbit in about 600 years. These results are extremely rough, depending as they do on changes in the small quantities dN and dI.

Graphic Solution of the Question.—The positions of the pole of the orbit are given by $\alpha = 90^\circ + \mathrm{N}$ and $\mathrm{D} = \mathrm{N.P.D.} = 180^\circ - \mathrm{I}$.

e six epochs considered, the values of α and D are g
cond and third columns of the following table :

R.A. of Pole of Orbit $= \alpha$.	N.P.D. of Pole of Orbit D.	$\sin(\alpha - 270^\circ) \tan \frac{D}{2}$ $= y$.	$\cos(\alpha-$
$269^\circ \cdot 12$	$54^\circ \cdot 00$	$-\cdot 008$	+
$271 \cdot 49$	$55 \cdot 80$	$+\cdot 014$	+
$273 \cdot 10$	$58 \cdot 53$	$+\cdot 030$	+
$274 \cdot 36$	$59 \cdot 92$	$+\cdot 044$	+
$275 \cdot 27$	$60 \cdot 83$	$+\cdot 054$	+
$277 \cdot 58$	$62 \cdot 60$	$+\cdot 081$	+

e best small circle is to be drawn through the six
ler to exhibit this graphically let a stereographic
e made by producing lines from the south pole t
points to meet the tangent plane at the north pol
l circle on a sphere is projected into a small circle
the problem becomes one of plane geometry.

[redacted]

Date.	Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.	$\frac{da}{a}$.		s sin dp.	Residual.
1902.		"	"	"	"	"	"		"	"
'eb. 17	3	−4·2	+4·9	− 2·3	+0·9	+8·8	+15·6	=	+ ·20	+·08
18	3	+1·0	−2·6	−12·5	+5·1	−2·0	+10·8	=	− ·01	−·14
23	1	−4·9	+5·6	− 3·2	+1·2	+8·9	+15·1	=	− ·02	−·14
26	1	−5·4	+6·1	− 4·2	−1·5	−9·0	+14·6	=	+ ·16	+·04
28	3	+2·7	−3·3	− 0·4	+1·4	+8·4	+16·2	=	+ ·30	+·22
ar. 3	3	+2·4	−3·0	− 0·3	−1·4	−8·4	+16·2	=	+ ·10	+·02
6	3	+1·5	−1·8	0·0	+1·3	+8·3	+16·4	=	+ ·19	+·11
11	2	+5·3	−7·4	− 8·3	−2·1	+7·7	+12·0	=	+ ·27	+·17
13	1	−5·7	+6·0	− 8·2	+3·3	+7·8	+12·6	=	+ ·21	+·07
15	2	−0·3	+0·3	0·0	−1·0	−8·2	+16·4	=	+ ·18	+·09
16	2	−4·9	+4·7	−10·1	−4·3	−6·3	+11·7	=	− ·15	−·30
21	2	−1·5	+1·8	− 0·4	−0·9	−8·2	+16·3	=	+ ·56	+·46
26	1	+5·6	−7·3	− 3·9	−0·4	−8·9	+13·9	=	+ ·16	+·07
r. 14	1	−5·1	+5·8	− 3·8	−1·3	−8·7	+14·3	=	− ·04	−·16
16	1	+3·1	−3·8	− 0·6	+1·3	+8·3	+15·6	=	− ·02	−·10
17	1	−5·4	+6·1	− 4·7	+1·7	+8·7	+13·9	=	− ·15	−·27
24	1	+4·6	−6·5	− 9·2	+2·8	−6·7	+11·3	=	− ·01	−·11
27	1	+5·0	−7·0	− 8·4	−2·3	+7·4	+11·6	=	− ·17	−·26

Equations of Condition.

Position-angle.

Date.	Weight.	sin du.	sin dN.	sin dI.	$2e$ sin Q.	$2e$ cos Q.		s sin dp.	Residual.
1903.		"	"	"	"	"		"	"
Dec. 4	1	−11·2	−5·9	−2·8	+10·9	+ 2·4	=	+0·13	−·11
8	1	−13·9	+1·4	+7·9	− 7·8	+11·4	=	+ ·26	+·11
9	2	−15·4	+4·4	−6·3	+ 6·5	+14·0	=	+ ·25	+·07
10	2	−11·1	−6·4	−1·1	+11·0	+ 0·9	=	+ ·33	+·09
14	1	−14·2	+2·1	+7·9	− 7·4	+12·1	=	+ ·11	−·04
15	1	−14·6	+2·6	−7·2	+ 7·8	+12·4	=	+ ·29	+·08
17	1	−14·5	+2·9	+7·7	+ 6·9	−12·7	=	+ ·05	−·09
30	2	−12·8	−1·8	−7·0	− 9·9	− 8·1	=	+ ·22	−·01
31	2	−11·4	−5·2	+4·6	−10·6	+ 4·2	=	+ ·29	+·07
1904. Jan. 6	1	−11·6	−4·4	+5·7	−10·3	+ 5·4	=	+ ·26	+·05
13	2	−16·9	+7·7	+0·3	+ 0·7	+16·9	=	+ ·23	+·08
14	2	−11·7	−4·6	−4·9	+10·8	+ 4·7	=	+ ·27	+·02
15	3	−12·2	−2·7	+7·2	+ 9·6	− 7·5	=	+ ·26	+·08
19	2	−16·6	+7·0	−2·9	+ 3·6	+16·2	=	+ ·15	−·01
22	1	−16·7	+7·2	−2·3	− 3·1	−16·4	=	+ ·16	·00
Feb. 2	1	−14·0	+2·0	+8·0	+ 7·2	−12·0	=	− ·23	−·37

Weight.	sin *du*.	sin *d*N.	sin *d*I.	2*e* sin Q.	2*e* cos Q.		*s* sin *dp*.	Residual.
4	−14″·2	+2″·7	+7″·9	−6″·8	+12″·5	=	+″·13	−″·02
1	−14·6	+2·6	−6·9	+8·0	+12·2	=	+·07	−·13
2	−10·9	−6·3	+1·8	+10·8	−1·6	=	+·18	−·05
2	−13·4	−0·2	−7·2	−9·4	−9·5	=	+·30	+·07
2	−15·8	+6·1	+5·3	−3·5	+15·4	=	+·05	−·08
2	−11·3	−5·1	−3·9	−10·6	−3·7	=	+·13	−·10
4	−12·3	−1·5	+7·7	−8·8	+8·6	=	+·19	+·02
2	−14·8	+3·7	−6·2	−7·1	−13·0	=	+·31	+·12
2	−10·7	−5·7	+3·2	+10·3	−2·8	=	+·26	+·04
1	−10·8	−5·0	+4·6	+10·0	−4·1	=	+·34	+·14
2	−16·0	+7·2	+1·8	−0·4	+16·0	=	+·16	+·03
2	−11·2	−3·8	+6·1	+9·5	−5·8	=	−0·02	−·21

Equations of Condition.

Distance.

eight.	sin *du*.	sin *d*N.	sin *d*I.	2*e* sin Q.	2*e* cos Q.	$\frac{da}{a}$.	*s* sin *dp*.	Resi-

Date.	Weight.	sin *du*.	sin *dN*.	sin *dI*.	2*e* sin Q.	2*e* cos Q.	$\frac{da}{a}$.		*s* sin *dp*.	Residual.
1903.		"	"	"	"	"	"		"	"
Mar. 10	2	+3·7	−4·6	− 1·1	+0·9	+8·6	+15·7	=	+ ·06	+ ·02
11	4	−5·4	+6·2	− 4·2	+1·2	+8·9	+14·4	=	− ·09	− ·13
21	2	+4·9	−6·6	− 9·0	−2·8	+7·1	+11·8	=	+ ·24	+ ·18
Apr. 6	2	−1·7	+2·1	− 0·4	−0·4	−8·2	+16·1	=	+ ·36	+ ·34
12	1	−2·8	+3·4	− 1·0	−0·4	−8·4	+15·7	=	+ ·26	+ ·23
16	2	−1·4	+0·9	−12·1	+5·3	+1·5	+10·6	=	+ ·09	+ ·02
18	2	−4·0	+4·8	− 2·0	−0·5	−8·6	+15·1	=	+ ·22	+ ·18

Normal Equations.

1902.

	sin *du*.	sin *dN*.	sin *dI*.	2*e* sin Q.	2*e* cos Q.	$\frac{da}{a}$.		
sin *du*	9927	−1504	+ 96	+1131	+1189	+ 930	=	−148·14
sin *d*N		2684	+ 687	+ 139	− 660	−1602	=	− 4·44
sin *d*I			3935	+ 141	+ 120	−3295	=	− 31·88
2*e* sin Q				4241	+1516	− 169	=	− 19·34
2*e* cos Q					8059	+1260	=	− 15·47
$\frac{da}{a}$						9526	=	+ 53·08

1902–03.

	sin *du*.	sin *dN*.	sin *dI*.	2*e* sin Q.	2*e* cos Q.	$\frac{da}{a}$.		
sin *du*	11430	− 673	− 400	− 406	+1106	+ 222	=	−123·09
sin *d*N		3060	+ 158	− 280	− 301	− 618	=	− 18·17
sin *d*I			4120	+ 528	− 69	− 3471	=	− 36·90
2*e* sin Q				5479	+ 628	− 86	=	+ 7·39
2*e* cos Q					9307	− 590	=	+ 1·77
$\frac{da}{a}$						13333	=	+ 93·48

1903–4.

	sin *du*.	sin *dN*.	sin *dI*.	2*e* sin Q.	2*e* cos Q.	$\frac{da}{a}$.		
sin *du*	10146	−1547	− 710	− 108	−2758	− 581	=	−127·67
sin *d*N		2468	− 175	− 334	+1233	+ 496	=	− 5·87
sin *d*I			4232	− 715	+ 230	− 3579	=	− 8·18
2*e* sin Q				3956	− 210	+ 563	=	+ 2·70
2*e* cos Q					8714	− 12	=	+ 26·23
$\frac{da}{a}$						10074	=	+ 34·39

Revised Elements of UY Cygni (*Ch.* 7514).

R.A. = $20^h\ 52^m\ 16^s$, Decl. = $+30°\ 2'{\cdot}8$ (1900).

By A. Stanley Williams.

period of $13^h\ 27^m\ 20^s{\cdot}85$ found for this variable star in
was based on the assumption that a photograph obtained
1900 November 22 was taken when the star was either
at any rate very near, its maximum brightness. The ob-
ons of the summer and autumn of the same year showed,
r, that this period was somewhat too short, and it appears
e star was really nearly an hour and a half past maximum
time when the photograph above referred to was taken.
Hartwig obtained a period of $13^h\ 27^m\ 27^s{\cdot}59$ from the
ison of two maxima observed by him on 1902 June 28
03 October 28.† In the present note fresh elements have
erived from the visual observations of the three years
903, and 1904.
le I. contains all the observed times of T_0, that is, the time
he variable in its rapid rise from minimum attained to
y with the comparison star c ($10^m{\cdot}2$).‡ These observations

Table II. gives in similar form the observations of maximum. The two marked with an H in the last column were observed by Hartwig at Bamberg, the others by the writer. The photographic observation of 1900 November 22, alluded to above, has been added for comparison. As already remarked, it is nearly an hour and a half later than the actual time of maximum. Both the times of T_0 in Table I. and those of maximum in Table II. were ascertained chiefly by means of single curves, though a mean light-curve was made use of in cases of uncertainty, or whenever this seemed desirable.*

TABLE II.

Observed and Computed Times of Maximum.

E.	Date.	Observed Maximum.	Red to ⊙.	Helio-centric Maximum.	Computed Maximum.	O−C.	
		h m	m	h m	h m	m	
0	1900 Nov. 22	[10 55]	−0·4	[10 54·6]	9 26·3	[+88·3]	p
1040	1902 June 28	...	...	12 30	12 46·1	−16·1	H
1072	July 16	11 40	+5·5	11 45·5	11 23·6	+21·9	
1138	Aug. 22	11 29	+6·5	11 35·5	11 33·5	+ 2·0	
1145	26	9 32	+6·5	9 38·5	9 45·5	− 7·0	
1147	27	12 29	+6·5	12 35·5	12 40·3	− 4·8	
1186	Sept. 18	9 34	+5·8	9 39·8	9 29·8	+10·0	
1293	Nov. 17	9 13	+0·3	9 13·3	9 24·0	−10·7	
1634	1903 May 27	13 53	+0·7	13 53·7	14 15·2	−21·5	
1641	31	12 31	+1·1	12 32·1	12 27·2	+ 4·9	
1789	Aug. 22	12 5	+6·5	12 11·5	12 5·8	+ 5·7	
1814	Sept. 5	12 19	+6·3	12 25·3	12 31·4	− 6·1	
1821	9	10 33	+6·2	10 39·2	10 43·4	− 4·2	
1830	14	11 38	+6·0	11 44·0	11 50·1	− 6·1	
1846	23	11 3	+5·5	11 8·5	11 8·9	− 0·4	
1908	Oct. 28	...	...	5 45·0	5 29·0	+16·0	H
2390	1904 July 24	11 42	+6·0	11 48·0	11 46·9	+ 1·1	
2408	Aug. 3	13 49	+6·3	13 55·3	14 0·5	− 5·2	
2417	8	15 1	+6·4	15 7·4	15 7·3	+ 0·1	
2422	11	10 19	+6·5	10 25·5	10 24·4	+ 1·1	
2424	12	13 23	+6·5	13 29·5	13 19·3	+10·2	
2463	Sept. 3	10 7	+6·3	10 13·3	10 8·8	+ 4·5	
2488	17	10 49	+5·9	10 54·9	10 34·3	+20·6	
2504	26	9 46	+5·3	9 51·3	9 53·1	− 1·8	

A period of $0^d{\cdot}5607082$ was derived from the observations of T_0, and one of $0^d{\cdot}5607125$ from the observations of maximum;

* All the times in the year 1902 were derived by means of a mean light-curve.

ving the two results equal weight, the following are the elements of variation of *UY Cygni* :

$$T_0 = 1900 \text{ November } 22,\ 8^h\ 3^m{\cdot}5 \text{ (G.M.T.)}$$
$$+13^h\ 27^m\ 25^s{\cdot}37\ E$$
$$= \text{J.D. } 2415346{\cdot}3358 + 0^d{\cdot}5607103\ E$$
$$\text{ximum} = 1900 \text{ November } 22,\ 9^h\ 26^m{\cdot}3 \text{ (G.M.T.)}$$
$$+13^h\ 27^m\ 25^s{\cdot}37\ E$$
$$= \text{J.D. } 2415346{\cdot}3933 + 0^d{\cdot}5607103\ E$$

times of T_0 and of maximum according to these elements found in the sixth columns of the foregoing tables, and ferences O−C in the last columns.

Note on the Variable RZ Lyræ.

R.A. $= 18^h\ 39^m\ 54^s$, Decl. $= +32°\ 41'{\cdot}7$ (1900).

out 400 observations of the brightness of this star have otained during the past two years ; but as the elements ed in the *Ast. Nach.* 3880 still indicate the time of

time when the variable in its rapid rise from minimum attained to equality with the comparison star l ($12^{m}\cdot1$). These observations were all made by the writer with a 6½-inch reflector, excepting that of 1901 October 25, which is derived from the observations by Dr. E. Hartwig at Bamberg, published in the note at the foot of page 205 of vol. lxii. of the *Monthly Notices.* The different columns of the table will sufficiently explain themselves. The approximate corrections for the equation of light have been applied, although this correction is never very large in the case of *Y Lyræ.*

TABLE I.

Observed and Computed Times of T_o.

E.	Date.	Observed T_o.	Red to ☉.	Helioc T_o.	Computed T_o.	O–C.	
	1901	h m	m	h m	h m	m	
1184	Aug. 18	10 22	+2·4	10 24·4	10 11·0	+13·4	
1186	19	10 10	+2·3	10 12·3	10 18·8	− 6·5	
1188	20	10 10	+2·3	10 12·3	10 26·5	−14·2	
1190	21	10 30	+2·3	10 32·3	10 34·3	− 2·0	
1192	22	10 40	+2·2	10 42·2	10 42·1	+ 0·1	
1194	23	10 41	+2·2	10 43·2	10 49·9	− 6·7	
1196	24	10 50	+2·2	10 52·2	10 57·6	− 5·4	
1200	26	11 11	+2·1	11 13·1	11 13·1	0 0	
1218	Sept. 4	12 7	+1·7	12 8·7	12 22·9	−16·2	
1309	Oct. 20	6 11	−0·7	6 10·3	6 15·8	− 5·5	
1319	25	7 2	−1·0	7 1·0	6 54·7	+ 6·3	H
1337	Nov. 3	8 12	−1·5	8 10·5	8 4·6	+ 5·9	
	1902.						
1757	June 2	11 13	+2·7	11 15·7	11 13·6	+ 2·1	
1918	Aug. 22	9 30	+2·2	9 32·2	9 38·2	− 6·0	
1950	Sept. 7	11 49	+1·6	11 50·6	11 42·3	+ 8·3	
1952	8	11 52	+1·6	11 53·6	11 50·1	+ 3·5	
	1903.						
2521	June 21	12 37	+2·7	12 39·7	12 37·2	+ 2·5	
	1904.						
3231	June 12	10 35	+2·9	10 37·9	10 31·2	+ 6·7	
3243	18	11 20	+3·0	11 23·0	11 17·8	+ 5·2	
3400	Sept. 5	9 22	+1·6	9 23·6	9 26·8	− 3·2	
3408	9	9 50	+1·5	9 51·5	9 57·7	− 6·2	
3410	10	10 3	+1·5	10 4·5	10 5·5	− 1·0	

Table II. gives in similar form the observed times of maximum. Those marked with H in the last column were observed by Hartwig at Bamberg,* the others by the writer. The three observations marked with a "p" are the three

* *V.J.S. der Astron. Gesell.*; Jahrgang 36, Heft 3/4, p. 268.

graphic observations previously alluded to. They
n the calculations, and have been inserted here m
ke of comparison.

TABLE II.

Observed and Computed Times of Maximum.

Date.	Observed Max.	Red to ☉.	Helioc. Max.	Computed Max.
1899.	h m	m	h m	h m
Dec. 31	[6 43·5]	−3·1	[6 40·4]	6 35·3
1900.				
Sept. 3	[14 17·5]	+1·8	[14 19·3]	14 16·0
1901.				
Aug. 18	[11 51]	+2·4	[11 53·4]	11 7·9
19	11 32	+2·3	11 34·3	11 15·7
20	11 34	+2·3	11 36·3	11 23·4
21	11 33	+2·3	11 35·3	11 31·2
22	11 33	+2·2	11 35·2	11 39·0
23	11 45	+2·2	11 47·2	11 46·8
24	12 13	+2·2	12 15·2	11 54·5
26	12 11	+2·1	12 13·1	12 10·0
Sept. 4	[illegible]	[illegible]	[illegible]	[illegible]

Giving the former result double weight, the following are the revised elements of variation of *Y Lyræ*:

$$\begin{aligned} T_0 &= 1899 \text{ Dec. } 31,\ 5^h\ 38^{m}\!\cdot\!4 \text{ (G.M.T.)} + 12^h\ 3^m\ 52^{s}\!\cdot\!74 \text{ E} \\ &= \text{J.D. } 2415020\cdot2350 + 0^{d}\!\cdot\!5026937 \text{ E} \\ \text{Maximum} &= 1899 \text{ Dec. } 31,\ 6^h\ 35^{m}\!\cdot\!3 \text{ (G.M.T.)} + 12^h\ 3^m\ 52^{s}\!\cdot\!74 \text{ E} \\ &= \text{J.D. } 2415020\cdot2745 + 0^{d}\!\cdot\!5026937 \text{ E} \end{aligned}$$

The computed times of T_0 and of maximum will be found in the sixth columns of the foregoing tables, and the differences O—C in the last columns. With reference to these latter it should be noted that Hartwig seems to have systematically observed the maxima earlier than the writer, and that the grouping of the residuals is suggestive of the existence of subjective influences. In particular the late maximum of 1901 August 18, the first visually observed, is probably due to a struggle on the part of the observer against the rapid decline in brightness after maximum. There are no observations of maximum in 1903 and only one of T_0. *Y Lyræ* is rather a faint variable for observation with a 6½-inch aperture, and a very clear night and absence of moonlight are essential in order to obtain a satisfactory series of observations. In the year above mentioned unfortunately all the clear and cloudless nights, when the maxima were observable, occurred when there was a bright moon. All the times of T_0 and of maximum given in the preceding tables and observed here were derived from single curves, though, as regards the maxima at any rate, a somewhat greater accordance might have been obtained by the use of a mean light-curve.

It should be mentioned that a slightly different light-scale was used in reducing the observations of 1902–4. In 1901 the observations had been made with the eyes kept normal to a line joining the stars A and *b* (see the diagram in the *Monthly Notices*, vol. lxii. p. 201), but in the subsequent years they were made with the head so held that the eyes were parallel to a straight line joining the two stars undergoing comparison. The following is the light-scale used in reducing the observations of 1902–4, with the assumed magnitudes of the comparison stars:

Star.	Light-scale.	Mag.
d	38·4	10·11
c	29·9	10·70
h	15·8	11·69
l	10·0	12·10

It does not seem likely that any sensible difference will have been caused in the time of T_0 by the change of scale, the position of the comparison star relative to the minimum brightness of the variable being nearly the same in both scales.

Hove: 1905 *March* 9.

Value of Meteoric Radiants based on Three Paths.
By W. F. Denning.

h regard to the validity of radiants derived from only
aths, discussed mathematically by Mr. H. W. Chapman
y *Notices*, 1905 January, p. 238), I would like to offer
marks from an observer's point of view.

believe that, as a rule, radiants determined from three
re useless or at least extremely doubtful, especially when
rvers responsible for them have not gained considerable
ce in meteoric work.

here are particular cases, however, where three meteors
icate good radiants, and these are when the latter are low
ude or very near the horizon. In such instances the
traverse long paths; they have comparatively slow
ascending, and the discriminating observer can entertain
t as to the place of divergence. On the other hand, the
uncertainty must attach to short, swift meteors falling
ertically in low positions. When the flights of these are
back in the same lines they may each cross a dozen or
tive radiants.

Inder ordinary circumstances it is far from safe to accept

e positions and the conditions affecting the determination case.

ꞁs a partial safeguard against pseudo-radiants I would that no radiant be accepted depending upon less than five *nless the circumstances are special.* It is true that certain : systems—in fact a large majority of them—are so that to gather five paths from any of these positions may ate forty or fifty hours of watching by one observer, and ny such showers must altogether escape detection if the a proved radiant be placed at five members. But I feel .t it will be best in the end to reject all very slenderly ɔd showers *indicated under ordinary conditions.* Even t proficient observers are sometimes led astray by insuf- naterials, and meteoric streams are so abundant that it safer to recognise such results only as can be fairly well tiated by adequate data.

ꞁxception might occasionally be made in cases where the : has acquired extensive experience, and where he has ıly registered three or four meteors under circumstances favouring the detection of their radiant.

Observers should keep a list of feebly suspected showers :h during the progress of observation and endeavour to ·ate them at similar epochs in following years. By com- materials in this manner good and amply supported ı may often be obtained.

[have sometimes secured certain evidence of radiants ly two, three, or four tracks when the positions have been ı horizon. Thus on 1878 July 28 only two paths served : a centre at $33^\circ - 20^\circ$ in the eastern region of *Cetus* :—

	G.M.T.	Mag.	From	To	Length.
	h m		° °	° °	°
28	13 32	1	2 + 0	336 + 17	31
	14 32	2	55 + 44	126 + 74	41

886 April–May I recorded three meteors from a radiant *io* at about 254°–20° :—

		Mag.	From	To	Length.
	h m		° °	° °	°
30	11 39	4	249¾ + 34	240 + 76	36
5	14 29	2	287½ − 5	315 + 9½	31
6	10 37	2	233½ + 26½	202 + 57	38

ıston, Bristol :
5 *March* 18.

On the Spherical Correction of Object-glasses.

By A. E. Conrady.

performance of object-glasses and mirrors is influenced
nsiderably by unavoidable residuals of spherical aberra-
The usual treatment of these residuals, and of spherical
on in general, by purely geometrical methods, *i.e.* as
f a more or less serious confusion of the "rays" forming
ge, is decidedly unsatisfactory from the physical point
, for the undulatory theory defines a perfect lens or
as one which brings all light from a luminous point to
us *in the same phase of vibration*, or which, in other
transforms the spherical waves sent out by the object
ly spherical waves converging towards the focus. From
nt of view any defects in a lens or mirror can become
only in so far as they sensibly throw certain portions of
l light *out of phase* with other portions; and there can
doubt that the differences of phase with which the
t portions of the total light meet at the focus are the
ie and absolute measure of the seriousness of any out-
g aberrations.

common focus of the axial and marginal rays; for it will be seen by reference to fig. 1 that only a generating line like that drawn can produce a surface with an arrangement of normals such as the geometrical theory proves to exist.

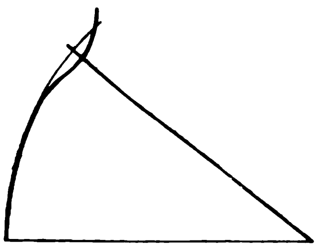


FIG. 1.

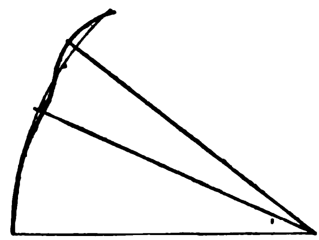


FIG. 2*a*.

In the case of lens-systems which contain deeply curved lenses, and in which the spherical residuals might attain prohibitive magnitude, the correction is sometimes carried a step farther by uniting the paraxial and the marginal rays with those passing through some selected intermediate zone. Further computation then again shows that all other zones are defective, and we can estimate that the real wave-form must be of the nature of those shown in fig. 2*a*, *b*, *c*, ; that it may indeed be any surface of rotation having the centre of curvature of its paraxial

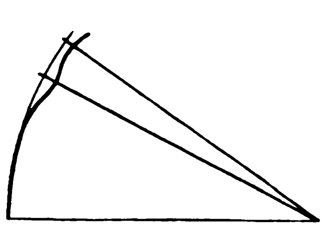


FIG. 2*b*.

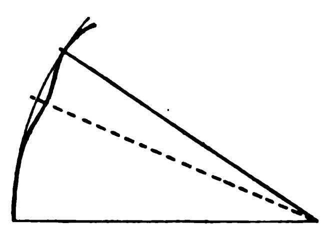


FIG. 2*c*.

portion in the computed focus, and having two other zones the normals of which are directed towards the same focus. The most interesting result of the above simple and elementary considerations is probably this, that the zones for which spherical correction in the geometrical sense is established are apt to be the worst corrected in the physical sense. On the other hand the same considerations prove the desirability of practicable methods by which the *magnitude* of the existing differences of phase may be determined.

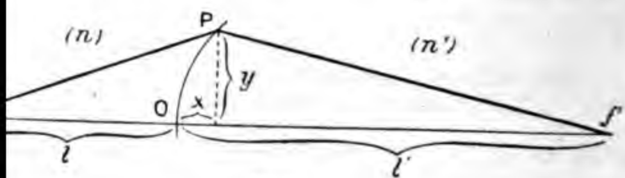
I say *practicable* methods because it would be a simple trigonometrical task to compute the *total* path of a number of rays through any lens-system; indeed, it will be seen by reference

paper on chromatic aberration* that the quantities D
used and trigonometrically defined represent successive
s of such paths ; but as the total path is measured by the
le and the wave-length by tenth-meters, it might occasion-
quire the hunting-up of a table of 10-figure logarithms to
the necessary accuracy.

formulæ to be sought for should therefore give the
ce between different optical paths in terms which are
bly small multiples of the wave-length.

first method fulfilling this condition which I succeeded
sing more than ten years ago is briefly this :

f O f' (fig. 3) be the optical axis of some lens-system;
efracting surface, f at the distance l from O a luminous
n the medium of refractive index n, to the left of the



generating line of a refracting surface which is aplanatic with regard to the conjugates f and f' (Cartesian ovals).

We will now restrict ourselves to a spherical surface of radius r; this gives us the well-known relation

$$y^2 = 2rx - x^2$$

between x and y. Introducing this for y^2 in I., and carrying out a few other obvious operations at the same time, we obtain

$$\text{I.*}\quad w = n'l'\left(1 - \sqrt{1 - 2\frac{x}{l'}\frac{l'-r}{l'}}\right) - nl\left(1 - \sqrt{1 - 2\frac{x}{l}\frac{l-r}{l}}\right)$$

putting

$$c' = \frac{x}{l'}\frac{l'-r}{l'} \qquad c = \frac{x}{l}\frac{l-r}{l}$$

and developing the square roots by McLaurin's theorem, we find

$$w = \begin{Bmatrix} n'l'(c' + \frac{1}{2}c'^2 + \frac{1}{2}c'^3 + \frac{5}{8}c'^4 + \frac{7}{8}c'^5 + \ldots \quad \ldots \quad \ldots) \\ -nl(c + \frac{1}{2}c^2 + \frac{1}{2}c^3 + \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots) \end{Bmatrix}$$

or separating the first-order terms

$$\text{II.}\quad w = n'l'c' - n.l.c + \begin{Bmatrix} n'l'c'^2(\frac{1}{2} + \frac{1}{2}c' + \frac{5}{8}c'^2 + \quad \ldots \quad \ldots) \\ -n.l.c^2(\frac{1}{2} + \frac{1}{2}c + \frac{5}{8}c^2 + \quad \ldots \quad \ldots) \end{Bmatrix}$$

The terms c' and c involve the abscissa x which in the case of a circle diminishes rapidly as P approaches the axis; hence for paraxial rays the first terms of II. will alone be sensible, giving ${}_0w = n'l'c' - nlc$.

If now we put ${}_0w = 0$ we obviously have the condition which makes f' the focus of the paraxial rays from f, for ${}_0w = 0$ means that all light passing from f through the paraxial zone arrives simultaneously at f' or becomes a spherical wave-train converging towards f'; and adopting this further restriction as to the points f and f' being paraxial conjugates, we have l' determined by the condition ${}_0w = 0$; for reintroducing the values of c and c' we obtain the condition

$$n'\frac{l'-r}{l'} = n\frac{l-r}{l} \text{ or } \frac{n'}{l'} = \frac{n}{l} + \frac{n'-n}{r}$$

which is arrived at in geometrical optics by a totally different method.

We now have for the focus of the paraxial rays thus determined

$$w = n'l'c'^2(\tfrac{1}{2} + \tfrac{1}{2}c' + \tfrac{5}{8}c'^2 + \ldots) - nlc(\tfrac{1}{2} + \tfrac{1}{2}c + \tfrac{5}{8}c^2 + \ldots)$$

The rigorous numerical computation of this would complete our task. And this is *possible* because the c and c' are, in all practical cases, limited to a narrow range of values, from about

o + ·3 ; hence we can prepare a table * giving the numerical
f the round brackets for any practically possible c, really
short and easily computed table. The series itself can be
r the small values of c usually occurring, whilst for the
values it is easy to see, by referring back to the original
n, that we have

$$f_{(c)} = \tfrac{1}{2} + \tfrac{1}{2}c + \tfrac{5}{8}c^2 + \ldots = \frac{1 - \sqrt{1 - 2c} - c}{c^2}$$

at the value of the series may be obtained from this
a. Calling this tabulated value of the series $f_{(c)}$ we then
e simple formula for the difference of optical paths

$$w = n'l'c'^2 f_{(c')} - nlc^2 f_{(c)}$$

to this point the solution of the problem is a very simple
nvenient one ; but when applying it to a succession of
ing or reflecting surfaces, a troublesome correction has
taken into account which arises from the presence of
al aberration in the geometrical sense.
ation III. is rigorously correct for rays directed towards
us of the paraxial pencil, but as a rule the marginal rays
travel in that direction, being deflected through spherical

as refracted by the surface O_1P_1, F' the corresponding focus of the marginal rays refracted by the same surface, Equation III. assumes the light to proceed along the straight line P_1f'; according to the law of refraction the light takes the path P_1F', reaching the second surface at P_2.

Without entering into an extended discussion, it may be merely stated that the correction is found to be equal to the excess of the two sides $(P_1P_2 + P_2f')$ of the long triangle P_1P_2f' over the third side P_1f', and that the computation of this correction was often found to be the most troublesome part of the task. Still, in the case of ordinary telescope-objectives of the usual proportion of aperture to focus, the correction is almost insensible, and may safely be neglected; and in this case Equation III. may therefore be regarded as a complete and convenient solution of the problem. It is different, however, in lens-systems such as are found in microscope-objectives. Here the correction occasionally amounts to many wave-lengths, and becomes an essential part of the whole difference of optical paths.

It only remains to be added that by substituting $(n+dn)$ for n and $(n'+dn')$ for n' in Equation I. and reducing in a manner analogous to that applied to I. an expression may be obtained which allows of the correction of chromatic aberration in a manner analogous to that treated of in my paper on chromatic correction. As the method given in that paper is more convenient, I will not give the modification in detail.

As the troublesome correction mentioned above arises because the marginal rays are not directed towards the focus of the paraxial rays which is the point of reference in Equation III., this correction would obviously disappear if the point of intersection of the marginal rays with the optical axis were taken instead.

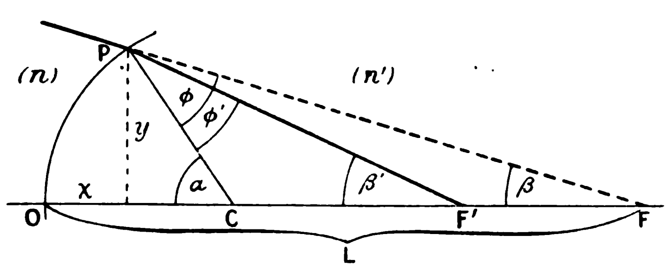


Fig. 5.

Realising this, I endeavoured for years to find a convenient solution of the problem on this basis, but until recently without success. As the path of a marginal ray can be conveniently defined and computed only by trigonometrical equations, it was obvious that the solution would have to be a trigonometrical one also.

is often the case, the finding of the elegant formula which depended on the choice of suitable variables and a " transformation.

trigonometrical formulæ by which the course of rays optical systems is defined were given in the former repeatedly quoted; referring to fig. 5 here reproduced, e defined by the abscissa OF = L and the angle of conce β, and if the coordinates of the refracted ray are disned by a dash the relations between the quantities are

$$1. \quad \sin\phi = \sin\beta\,\frac{L-r}{r}$$

$$2. \quad \alpha = \beta + \phi$$

$$3. \quad n'\sin\phi' = n\sin\phi$$

$$4. \quad \beta' = \alpha - \phi'$$

$$5. \quad L' - r = r\,\frac{\sin\phi'}{\sin\beta'}$$

assume that the course of the rays to be considered has mputed by these equations, and that the quantities conin them are therefore known.

the marginal ray; hence if these two optical paths are separately computed and found to differ, the difference is due to, and is a measure of, the spherical aberration produced by the surface OP, and is therefore the quantity we are trying to determine.

To obtain an expression for the length of AP we transfer it to the optical axis by a circle, PP′, with F as centre, so that

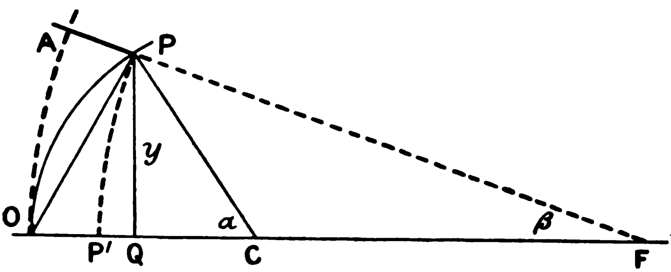


Fig. 7.

OP′ = AP (fig. 7). Dropping a perpendicular y from P upon the optical axis, we see that OP′ = OQ−P′Q.

Drawing OP, we have in the isosceles triangle OCP the angle at O $= 90° - \frac{\alpha}{2}$; hence in the right-angled triangle OQP

$$OQ = y \tan \frac{\alpha}{2}$$

Similarly we find

$$P'Q = y \tan \frac{\beta}{2}$$

hence

$$OP' = AP = y \left(\tan \frac{\alpha}{2} - \tan \frac{\beta}{2}\right)$$

Applying the same process in the determination of the length of OB we find

$$OB = y \left(\tan \frac{\alpha}{2} - \tan \frac{\beta'}{2}\right)$$

Multiplying the two paths by the respective refractive indices, we obtain the optical paths; their difference W is therefore

$$\text{IV.} \quad W = n'y\left(\tan \frac{\alpha}{2} - \tan \frac{\beta'}{2}\right) - ny\left(\tan \frac{\alpha}{2} - \tan \frac{\beta}{2}\right)$$

This equation may be further reduced in a few steps by the following transformations:

lacing tan by $\frac{\sin}{\cos}$ in Equation IV. we obtain by cross-ication

$$W = n'y\frac{\sin\frac{\alpha-\beta'}{2}}{\cos\frac{\alpha}{2}\cos\frac{\beta'}{2}} - ny\frac{\sin\frac{\alpha-\beta}{2}}{\cos\frac{\alpha}{2}\cos\frac{\beta}{2}}$$

by (4) $\frac{\alpha-\beta'}{2} = \frac{\phi'}{2}$ by (2) $\frac{\alpha-\beta}{2} = \frac{\phi}{2}$

$$W = n'y\frac{\sin\frac{\phi'}{2}}{\cos\frac{\alpha}{2}\cos\frac{\beta'}{2}} - ny\frac{\sin\frac{\phi}{2}}{\cos\frac{\alpha}{2}\cos\frac{\beta}{2}}$$

tiplying the first term by $\frac{2\cos\frac{\phi'}{2}}{2\cos\frac{\phi'}{2}}$, the second by $\frac{2\cos\frac{\phi}{2}}{2\cos\frac{\phi}{2}}$,

wo of which cross out, whilst the other two combine, with this esult :

$$\text{V.} \qquad W = \frac{n' \cdot y \cdot \sin\phi' \sin\frac{\beta-\beta'}{2} \sin\frac{\phi-\beta'}{2}}{2\cos\frac{\alpha}{2}\cos\frac{\beta}{2}\cos\frac{\phi}{2}\cos\frac{\beta'}{2}\cos\frac{\phi'}{2}}$$

This remarkable equation is undoubtedly the simplest and learest *rigorous* expression to which the problem of spherical berration has ever been reduced, and its discussion is therefore s interesting as it is easy.

As the angles occurring in V. are usually small, we see that he important terms are those of the numerator, the denominator eing more in the nature of a correction.

If we now discuss the effect of variation of any of the five erms in the numerator, the first, n', tells us that, other things eing equal, the aberration is proportional to the refractive ndex. The second term, similarly, makes the aberration pro-ortional to the semi-aperture y; hence we can at once generalise hat in similarly constructed optical systems the residual aber-ations are proportional to the scale to which the different ystems are constructed, and therefore that residuals which would e immaterial in a small object-glass may easily become serious 1 a similar object-glass of large size.

The term $\sin\phi'$ next shows that the aberration is approxi-ıately proportional to the angle of refraction, and the following erm that it is also nearly proportional to the deflection produced y the refraction; these are both results which seem almost oregone conclusions, and call for no special notice. But now we ome to the last term, and in this are wrapped up some of the hief mysteries of object-glass construction; for this term can ecome zero when all the other quantities have finite values, and hen the course of the rays is therefore altered by refraction; it hus expresses the existence of points for which the sphere is free rom spherical aberration.

Let us discover these points.

$\frac{\phi-\beta'}{2}$ becomes zero when $\phi = \beta'$, which implies $\sin\phi = \sin\beta'$, nd, further, by (3) $\frac{n'}{n}\sin\phi' = \sin\beta'$. The vanishing of the last erm of V. therefore depends on the condition $\frac{\sin\beta'}{\sin\phi'} = \frac{n'}{n}$.

If we now refer again to fig. 5, the trigonometrical sine-law pplied to the triangle PCF′ gives us

$$\frac{\sin\beta'}{\sin\phi'} = \frac{r}{L'-r} = \frac{n'}{n}, \text{ or } L'-r = r\frac{n}{n'}, \text{ or (6) } L' = r\frac{n'+n}{n'}$$

ther, by (2) and (4) we have $\phi - \beta' = \phi' - \beta$, or, proceeding
e,

$$\sin\phi' = \sin\beta = \frac{n}{n'}\sin\phi, \text{ or } \frac{\sin\beta}{\sin\phi} = \frac{n}{n'}$$

, by the triangle PCF,

$$\frac{\sin\beta}{\sin\phi} = \frac{n}{n'} = \frac{r}{L-r};\ L-r = r\frac{n'}{n};\ (7)\ L = r\frac{n'+n}{n}$$

in $\phi = \sin\beta'$, combined with $\frac{n}{n'}\sin\phi = \sin\beta$, both equa-
ccurring in the above, give

$$(8)\quad \frac{\sin\beta}{\sin\beta'} = \frac{n}{n'} = \text{a constant},$$

h we may add, by combining (6), (7), and (8) :

$$(8^*)\quad \frac{L'}{L} = \frac{n}{n'} = \frac{\sin\beta}{\sin\beta'}$$

(6) and (7) the position of the pair of aplanatic points is

Referring once more to fig. 1 it will be seen that these new equations make it possible to compute the distance between the real refracted wave and the ideal one when spherical correction in the geometrical sense has been established and thus to obtain a trustworthy indication of the residual aberration; but an even more important application of the new equations when so used in conjunction with the usual trigonometrical computation lies in the higher correction of spherical aberration by adding to the usual geometrical condition, that the lens-system shall be so corrected that the marginal rays shall be directed towards the focus of the paraxial pencil, the further one *that the marginal rays shall also meet the paraxial ones without any difference of optical paths*, i.e. *in the same phase of vibration.*

This condition, which I believe to be quite original with me, is one which I have adopted as a definite standard in carrying spherical correction to higher perfection in all cases which call for it.

Equation IV. gives the difference between the marginal and axial paths; it may therefore be differentiated to find its variation with the wave-length—in other words the chromatic aberration—after the manner introduced by me in the paper quoted above. We obtain

$$\text{IV.}^* \quad \frac{\partial W}{\partial \lambda} = \frac{\partial n'}{\partial \lambda} \cdot y\left(\tan\frac{\alpha}{2} - \tan\frac{\beta'}{2}\right) - \frac{\partial n}{\partial \lambda} y \left(\tan\frac{\alpha}{2} - \tan\frac{\beta}{2}\right)$$

Really α, β, and β' are also variable with λ, but I have proved in the former paper (and it may be accepted immediately as a deduction from Fermat's theorem of the minimum optical path) that the contributions of these to $\frac{\partial W}{\partial \lambda}$ add up to zero, and that they need not therefore be taken into account. Hence IV.* is an alternative equation for the computation of lens-systems in such a way as to attain minimum focus for a prescribed wave-length. It may be modified in a manner similar to that applied to IV., giving

$$\text{VI.} \quad \frac{\partial W}{\partial \lambda} = \frac{\partial n'}{\partial \lambda} y \frac{\sin\frac{\phi'}{2}}{\cos\frac{\alpha}{2}\cos\frac{\beta'}{2}} - \frac{\partial n}{\partial \lambda} y \frac{\sin\frac{\phi}{2}}{\cos\frac{\alpha}{2}\cos\frac{\beta}{2}}$$

an expression which is at least as convenient as that given in the former paper, and which may advantageously be computed as a check.

By computing by the trigonometrical formulæ (1) to (5), and also by V. and VI., we may free a lens-system from spherical and chromatic aberration, although only one single ray has been followed through the system. This seems rather a startling proposition, and might at first sight seem simply absurd; it becomes

le when we consider that the method of optical paths has
cal path given without computation, *i.e.* the optical axis
This is perhaps one of the most striking illustrations of
er of these new methods of computation.

her interesting results follow on reducing V. to first-order
.e. applying it to rays sufficiently near the optical axis to
ne sines equal to their angles, and the cosines equal to
Adopting the nomenclature of the former paper, *i.e.* a
d index o for these paraxial angles, we obtain easily

$$_{\circ}W = \tfrac{1}{8}n'\,_{\circ}y\,_{\circ}\phi(_{\circ}\beta - {}_{\circ}\beta')(_{\circ}\phi - {}_{\circ}\beta')$$

not difficult to see by referring to fig. 5 that $_{\circ}\beta = \frac{_{\circ}y}{l}$;
$_{\circ}\beta' = \frac{_{\circ}y}{l'}$ from which by (2) and (4) $_{\circ}\phi$ and $_{\circ}\phi'$ may be
introducing these we find

$$\text{VII.} \quad _{\circ}W = \tfrac{1}{8}n'\frac{_{\circ}y^4}{r^2}\cdot\frac{l'-r}{l'}\cdot\frac{l'-l}{ll'}\cdot\frac{ll'-rl'-rl}{ll'}$$

hows that in the first approximation the differences of
ncrease with the fourth power of the aperture. Being
cal, Equation VII. may possibly supply an alternative

in order to get corresponding geometrical distances we must therefore divide them by the index of the medium, which in the case of VII. amounts to leaving out the factor n'. Bearing this in mind and putting the angle between the real and the ideal "ray" as ψ we deduce

$$\psi = \frac{\partial_0 W}{\partial_0 y} = \frac{1}{2}\frac{{}_0y^3}{r^2} \cdot \frac{l'-r}{l'} \cdot \frac{l'-l}{ll'} \cdot \frac{ll'-rl'-rl}{ll'}$$

and combining this with VII., we obtain the interesting relation

$$\frac{{}_0W}{\psi} = \frac{n'{}_0y}{4} \text{ or IX. } \psi = \frac{4\,{}_0W}{n'{}_0y}$$

By this equation we can approximately compute ψ from ${}_0W$, or *vice versa*; as it stands it of course gives ψ in radians and ${}_0W$ in the same unit of length in which y is measured. To obtain ψ in seconds of arc we must multiply the right-hand side with 206,265. If y, the semiaperture, is measured in inches, we may express ${}_0W$ in wave-lengths by dividing the right-hand side by 50,000, the approximate number of average light-waves in one inch; hence our equation for y in inches, ψ in seconds, and ${}_0W$ in approximate wave-lengths becomes, near enough,

$$\psi = 16\,\frac{{}_0W}{n'{}_0y}$$

which means that in an object-glass of two inches aperture ($y = 1$) one wave-length of physical aberration corresponds to 16 seconds of geometrical aberration, or a "circle of confusion" of 32 seconds.

Lord Rayleigh has shown that ${}_0W$ may become $\frac{1}{4}$ wave-length without serious deterioration of the image. Accepting this, we deduce for a 1-inch object-glass

$$\psi = \frac{16 \times \frac{1}{4}}{\frac{1}{2}} = 8 \text{ seconds}$$

or a circle of confusion of 16 seconds of arc as the geometrical aberration permissible. As the resolving power of an inch object-glass is about $4\frac{1}{2}$ seconds, this shows most clearly how utterly misleading the geometrical theory is. According to the latter we should have stars spread out into discs nearly four times as large as the resolving power; in reality the image is little worse than that of a theoretically perfect glass.

This is really borne out by practical experience; moderate amounts of spherical aberration are almost past detection at the focus; they only show up when the star image is expanded by "racking in or out." It will nevertheless prove a great surprise to the vast majority of practical opticians who, impressed by the

nconceivable smallness of a wave-length, consider it simply
to be asked to make the different paths equal within
on of this minute quantity; they would, however, be
nt if it were suggested that they could not bring the more
geometrical "rays" together within a circle of confusion
nding in size to the theoretical resolving power of the
lass. As I have just shown, it is far easier to attain
ayleigh's quarter-wave standard than to reach the circle-
sion limit usually adopted in geometrical optics.

rd Park, W.:
5 April 12.

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*General Design of Spectrographs to be attached to Equa-
ls of large aperture, considered chiefly from the point of
of Tremor-discs.* By H. F. Newall.

following note is an attempt to gain a general idea of
ensions of that spectrographic installation that forms the

of spectra under conditions that impose the need to use narrow rectangular slits. If the tremor-disc is large compared with the width of the slit only a slice of the circular disc is used, and the total light transmitted is proportional only to the diameter of the object-glass and not to its area; the economy of light is disregarded. If the slit is widened so as just to include the tremor-disc, or the effective part of it, the light collected is economically used; but to get the height of spectrum (length of spectral lines) needed for good measurements the star must trail, and the question becomes one of economy of time.

The spectrographic problem has more frequently been dealt with from the point of view of attaching a spectrograph to an existing telescope, and the question of the intensity of the light on the slit has been perhaps unduly emphasised. It has now become a matter of interest to deal with the subject from the point of view rather of transmission of light, and we have to dwell on an equation of continuity. In the following notes I deal chiefly with "transmissions." In our efforts to extend our search for knowledge to faint stars, or to apply very high power to bright stars, we are always struggling with under-exposed photographs; and, on the ground that the faintest image of a star that is ever attained in astronomical photography is $2''$ in diameter, I have sought to make the spectrographic image of such a star image the standard of comparison, or rather the point of departure; for such a star image is effectively the smallest that falls on the slit, and we must avail ourselves of as much of the light in it as possible. The balance of those two conflicting elements, the transmission at the slit and the transmission through the prisms, is the really important factor in the design of a stellar spectograph.

In dealing with resolving power and purity I have throughout adhered to the idea originally worked out by Rayleigh and by Schuster, except in so far as I have not adopted Schuster's definition of the *numerical* values, but have simply put $P = \lambda/\delta\lambda$, λ and $\delta\lambda$ being expressed in terms of the same unit of wave-length. This gives, as the unit of purity, that purity which would allow the resolution of lines which differ in wave-length by an amount equal to the mean of the wave-lengths of the two lines. I have refrained from introducing into these simple relations any considerations relating to the range of wave-lengths to be found in the individual bright or dark lines of actual spectra, for these, as it seems to me, relate to the sources of light to be investigated by the spectroscope and do not concern the power of the instrument.

Diffractional Method of Estimating Slit-widths.

Consider diffraction of light through a narrow slit, when a parallel beam (plane wave-fronts) of light falls upon it and the phenomena are studied on a screen placed at a distance, f, from

s. The distance between the *m*th dark diffraction band
ight of the centre and the *m*th dark band on the left is

$$2\xi = \frac{2m\lambda f}{s} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

is the distance from the centre to the *m*th dark band
ed on the screen. In the figure the positions of the 1st, 2nd,
l *m*th bands are indicated on both sides of the centre O.
cle be drawn on the screen with diameter *a* round O as
then the *m*th dark bands touch the circle when $2\xi = \rho$.

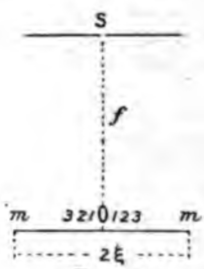


FIG. 1.

Ience $2p$ differs from $2m$ by nearly a constant quantity differing ittle from 0·5; and we may write equation (3)

$$d = \frac{(2m+\frac{1}{2})\lambda f}{a} = \frac{2m\lambda f}{a} + \frac{1}{2}\frac{\lambda f}{a} \quad \dots \quad \dots \quad (4)$$

Let us make use of the slit and collimator of a spectroscope to tudy the diffraction phenomena, and let us turn the slit towards . distant source of light; we shall find the diffraction pattern hrown on the object-glass of the collimator as on the screen and ircle of § 1, and we may adjust the slit to any desired width by bserving the scale of the diffraction pattern on the object-glass. 'he method is, I believe, well known to many spectroscopists; ut, as far as I am aware, the convenience of the method is not 'holly or generally recognised. Let us suppose that the object-lass has an aperture, a, and focal length, f, as in § 2. Then 'hen the mth band falls on the edges of the object-glass we know hat the slit has a width

$$s = \frac{2m\lambda f}{a}$$

ɔd by equation (4) we see that

$$s = d - \frac{1}{2}\frac{\lambda f}{a}$$

he small last term on the right prevents a perfectly concise ;atement of this relation; yet the following serves as a good ractical rule: When the slit-width is adjusted so that the ıth diffraction bands fall on the edges of the object-glass of the ɔllimator, then the slit has a width nearly equal to the diameter f the mth dark ring in the diffraction image of a star as seen ith the object-glass of the collimator.

I have adopted the custom of recording slit-widths in terms f these phenomena (*e.g.* slit $m = 1$, or slit $m = 4$); and as a ame is a convenience I would propose to call m the diffractional ıdicator.

In stellar spectroscopy it is generally arranged that the ratio ./F of the equatorial used to throw the star's image on the slit is ıe same as that of the collimator a/f. Under these circumstances ıe image of the star is a diffraction pattern of the same linear :ale as that due to the collimator. Hence we may put the prac-cal rule as follows. When the slit-width is adjusted (in parallel ght) so that the mth diffraction bands fall on the edge of the ɔject-glass of the collimator of a star spectroscope, its width is ıch as to include m maxima in the diffraction pattern of the ar's image on the slit. And, moreover, the geometrical image : the slit in the focal plane of the camera includes under these rcumstances just as many maxima in the diffraction pattern ɔpropriate to the camera.

purity of the spectrum depends on the width of the slit
If P represent purity of the spectrum, R the theoretical
g power of the spectroscope, and ψ the ratio $a/f = A/F$,
as the relation connecting purity, resolving power, and
ngth, according to Rayleigh and Schuster

$$P = \frac{\lambda}{s\psi + \lambda} R \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

by equation (2) we have

$$P = \frac{1}{2m+1} R$$

Wadsworth's relation is adopted as being nearer to observed
ns, we have

$$P = \frac{\lambda}{s\psi \cdot \frac{2s\psi - \lambda}{2s\psi + \lambda} + \lambda} R = \frac{1}{2m \cdot \frac{4m-1}{4m+1} + 1} R$$

have then for various values of m the following numerical
s between P and R :

m.	P (Schuster).	P (Wadsworth).

If the spectroscope is attached to an equatorial, it may be inconvenient to dismount it to judge of the width of the slit. In such case it is a good plan to diminish the aperture of the object-glass of the equatorial by means of a diaphragm till its effective diameter as seen from the slit is not greater than that of the Sun. The telescope is then pointed to the Sun and the adjustment of the slit can be readily made as above described.

A table is given on p. 626 showing the relation between the diffractional indicator and the actual slit-width in millimetres for collimators of various angular apertures, viz. $\frac{1}{10}$, $\frac{1}{15}$, $\frac{1}{19}$, $\frac{1}{20}$.

It is obvious that the readings of the micrometer screw provided for narrowing the slit may be recorded for each slit-width $m = 1$, $m = 2$, &c.; and when once the screw readings are calibrated in this manner (readings being taken only in the direction of *closing* the slit) the observer has complete control of the slit. A great advantage of the method lies in the fact that the dangerous operation of completely closing the slit for the purpose of determining the reading of the screw for zero width is avoided. Here also may be mentioned the need for special attention to the sharpness of the chisel-edge of each jaw of the slit. When the width of a slit is of the order of $0^{mm}.02$, the *depth* of the opening (as distinguished from the width and the length) asserts itself;

FIG. 2.

for usually the so-called sharp edge of each jaw has had the inequalities rubbed off, and the sharp edge is reduced to a flat face whose depth may easily amount to one or two hundredths of a millimetre without attracting attention.

The diffractional spreading of the beam that passes through a narrow slit enables us to utilise the whole resolving power of a spectroscope, even when the incident pencil on the slit has an angular aperture quite insufficient to "fill" the collimator and prisms. The admirable performance of a spectroscope when used with narrow slit for looking at sunlight without a condensing lens is well known to spectroscopists; see, for instance, Pulfrich, *Astroph. Jour.* i. p. 346 (*Zeitschr. f. Inst.*, 1894, p. 362): it is due partly to the fact that on account of diffractional spread the whole *width* of the prism system is utilised, and partly to the fact that the whole *height* is not used, and so some of the defects that are due to want of homogeneity or imperfect finish of the surfaces of the prisms and object-glasses do not have the chance of asserting themselves.

These diffraction bands are observed when a parallel beam falls on the slit; in most spectroscopic work it is a convergent beam which falls upon the slit.

With a view of forming some estimate of the amount of light

a stellar spectroscope on account of the diffractional
f the angular aperture of the beam passing into the slit,
consequent thrust of much of the light on to the stops in
mator, I made some experiments in 1896 ; but they seem
rdly worth putting on record in detail.
as only quite at the end of a troublesome set of experi-
hat I found a very elegant way of demonstrating this
onal spread of the light. It consists in making use of
ciple of optical reversibility. Take a collimator and turn
ct-glass towards the sky and view it through the slit, the
g held close to the slit. If the slit is wide the outline
bject-glass is seen equally well defined all round the cell;
the slit is narrowed, the edges become blurred and ill
(on the two *sides* when the slit is held vertical). A
narrowing of the slit results in the apparent spreading
he circular aperture of the object-glass into an oval figure
ll-defined edges at the ends of the shorter axis. Here,
easurement of the slit shows that diffractional spread
ven when $m > 4$, and is exceedingly marked when $m = 1$.
der will have no difficulty in working out the details of
ogy if I say that when a slit and collimator are supplied
from an equatorial the collimator object-glass is taking
e of the eye and looking through the slit at the equatorial

needed, the slit must have a diffractional indicator not less than $m = 3$, or possibly 4.

To gain further insight into the quantitative loss of light with different slit-widths, the following experiments were made in 1897, with especial reference to the attempt which I contemplated making to photograph the blue line in the spectrum of the corona in the eclipse of 1898. Monochromatic light was thrown upon a slit, and an image of the slit thus illuminated was thrown by means of a camera lens on a photographic plate. For each of a set of various slit-widths a series of these monochromatic images was photographed with different exposures, the plate being moved between successive exposures. An ordinary luminous gas-flame at G was used, and the light was passed through a single-prism spectroscope which was arranged in front of the experimental slit in such a manner that the violet part of the spectrum of the gas-flame fell upon it as indicated in the figure, thus affording constant (and approximately monochromatic) violet illumination of the slit. (In reality it is a narrow strip of continuous spectrum that is used.)

To estimate the width of the slit by the diffractional method a pinhole gas-flame was set up (as at P), so that light from it was reflected from the second surface of the prism on to the experimental slit. A reflecting prism which was placed when required between the camera lens and the photographic plate enabled the observer to adjust the slit-width without disturbing the plate or altering the violet illumination. By inserting an opaque screen near P or near G, either of the operations (*a*) adjusting the slit-width (in approximately parallel light), (*b*) taking photographs (in convergent light) with different exposures, could be completed without interfering with the constancy of illumination in either case; for neither of the gas flames was touched throughout the whole series of experiments. After a few trials it was easy to arrange a set of exposures which served well for the comparison of the various images.

The resulting photograph exhibited five rows of images with the following exposures (in seconds), the different rows corresponding to the slit-widths indicated by $m = 1$, $m = 2$, &c.:

$m = 1$	20	60	48	36	24	12	60	
$m = 4$	20	15	12	9	6	3	15	
$m = 3$	20	20	16	12	8	4	20	
$m = 2$	20	30	24	18	12	6	30	
$m = 1$	20	60	48	36	24	12	60	60

In comparing the photographic intensities of the various images one comes at the outset upon the well-known peculiarity of the eye, namely, that near the limit of visibility a broad line may be more readily detected than a very narrow one, even when the latter is of stronger intensity. Then with naked-eye

stimates I found representing the image got with
xposure and slit-width $m = 4$ by $(m_4, 3^s)$

$$(m_4, 3^s) > (m_3, 4^s) > (m_2, 6^s) > (m_1, 12^s) ;$$

ie images were nearly equally faint, but the wi
isregarded. On the other hand when an eyepiece
g ten-fold was used, the widths were obviously
tensity was then taken as the basis of visibility,
rder indicated above was completely reversed. Ac
estimating the photographic intensities of the i
icroscope with powers 15, 28 was used with the
sults :

Table showing Order of Images with respect to Density.

Densest Image.				
20	m_1 60			
19	m_1 48			
18	m_2 30			m_2 30
17	m_2 24			m_2 24
16	m_1 36			
15	m_3 20	m_4 20	m_3 20	m_2 20
14	m_2 18			m_2 18

least three times as wide before the loss of light ceases to be appreciable. To avoid misapprehension I may reiterate that, though the slit has been adjusted by the diffractional method in parallel light, the photographs were taken with a convergent beam falling on the slit.

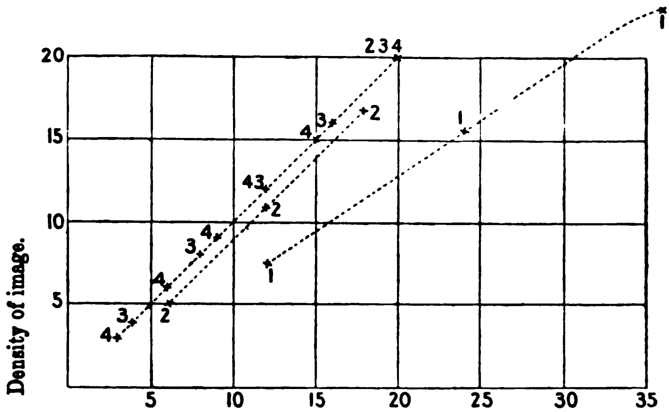


FIG. 4.

Equal photographic densities in the images may be attained with exposures 12 sec. for m_1 and $7^s.5$ for m_3 and m_4. This indicates that something like $37\frac{1}{2}$ per cent. of the light is lost in the image when the slit-width is $m = 1$. Again, equal densities obtain for exposures 24 sec. for m_1, and 15.5 for m_3 and m_4, indicating a loss of about 35 per cent. The approximate agreement between these results shows that the linear relation assumed between density and intensity is not far wrong for images as dense as those involved. [These results are in satisfactory agreement with those recently obtained by Mr. Moore at the Lick Observatory (*Astroph. Jour.* xx. 285).]

Thus it appears that when a slit-width $m = 3$ is used nearly five times as much light from the tremor-disc of a star passes through the collimator on to the prisms as when a slit-width $m = 1$ is used. For a slit $m = 4$, the figure becomes more nearly six and a half times. More careful measurements are, however, required; for it is probable that the loss by diffraction will depend to some extent upon the angular aperture of the pencil of light incident upon the slit.

As a result of these experiments I have aimed at using slit-widths not less than $m = 3$ whenever economy of light was of importance. The use of so wide a slit in stellar spectroscopy is rendered possible by the fact that the slit is illumined by a tremor-disc of considerable dimensions.

Considerations relating to the Tremor-disc.

perience shows that it is only under exceptional circum-
s that stellar photographs exhibit star-images of smaller
ter than 1″; and probably most observers would be content
smallest well-formed star-images on their photographs did
ceed 3″. This experience has been gained with refractors
flectors, large and small; and there is a general belief that
mospheric tremor is mainly responsible for the fact that
r images are not usually attainable. We may take it,
ore, that the smallest effective accumulative image of a
n the slit of a star-spectroscope is a "tremor-disc" of
ter 2″ or 3″ at least.

The name ["tremor-disc"] more or less explains itself; it
est to state what it is intended to convey by reference to a
graph of a star taken with a long exposure. The star
[diffraction pattern] moves about on the plate in con-
nce of atmospheric tremor, and produces its effect at each
n which it rests; the developed image is strongest where
ar has most frequently rested. The distribution of density
bably symmetrical about the mean position of the star, and
tensity at different points along a diameter of the resulting

off the axis in a trail of 26 seconds of time; seeing "very good $\frac{4}{5}$."

When two parallel lines were drawn down the axis of the trail to represent the width of the slit of a spectroscope on the magnified scale I found the following:

			Sec.	On Slit. sec.	Off Slit. sec.
(1) 1893 September 23	Seeing "very bad $\frac{1}{5}$"	Trail	27	11	16
(2) 1893 September 27	„ "very good $\frac{4}{5}$"	„	26	13	13

In very bad "seeing" the star was frequently crossing the slit; in very good "seeing" the star often remained stationary in declination for a second or more, sometimes on the slit, sometimes off.

These preliminary investigations seemed likely to lead me very far afield, and I even devoted some time to collecting photographs of trails of stars in different parts of the sky on a given night to see whether the direction of the wind made marked peculiarities in the trails, such as a suppression of the knots, which might be attributed to movements in right ascension, or an intensification of the declination movements. But it was clear to me that the important matter was the summation of these movements in time, and so I rested content with the concept of a tremor-disc which ought to guide us in our designs of spectrographs.

Distribution of Light in a Tremor-disc.

We should have perfect "seeing" and a perfect diffraction image of a star if the light from the star fell in plane wave-fronts with uniform distribution of intensity over the whole wave-front. Atmospheric disturbances upset not only the uniformity of distribution of light over an object-glass, but also the planeness of the wave-fronts; each wave-front must be regarded as buckled and corrugated and rippled in a way that changes from moment to moment on any given night, and on a scale that varies from night to night. For the purpose of making a numerical estimate I propose to regard atmospheric disturbances as producing two effects on the distribution of light in the focal plane of a telescope, (1) a scattering of light over a very considerable field (say 40″ or 50″), (2) a movement of the main concentration of light through small distances (say 5″) from the mean position. In the visually observed image we have a dancing star accompanied either by a fairly uniformly illuminated background or by a system of flashing rays; in a photograph we get the time-integral of these changes. For the sake of simplicity it will be convenient to use two names—"tremor-disc" and "scatter-disc."

In the "scatter-disc" we may sum up the light that is to all intents and purposes lost, so far as image is concerned, because it is spread over so wide a field [say 20″ radius (*Monthly Notices*, vol. liv. p. 376)] that its intensity is relatively negligible.

the "tremor-disc" we sum up the light that forms the
roper; in visual observations we set the wires of a micro-
o bisect an imaginary disc which the dancing momentary
uggests to our conception; the photograph gives us the
r parts of the tremor-disc as the image of a star.
all assume that a definite percentage of the light trans-
by the object-glass is scattered, and that this percentage
rom night to night and is proportional to the diameter of
ct-glass (not to its area), and I shall assume that the rest
ight goes into the tremor-disc, and that the dimensions of
mor-disc are independent of the aperture, and may vary
ur to hour.

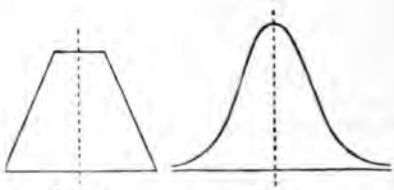


FIG. 5.—Conical. Errors.

The following table shows what fraction of the total quantity of light in a tremor-disc of diameter r'' is collected in the core of diameter γ'':

TABLE.

r'' =	2	3	4	5	6	7	8	9	10
$\gamma = 1''$	·43	·23	·14	·10	·07				
$\gamma = 2$		·63	·43	·38	·23	·18	·14	·12	·10

I propose now to deal with two cases: A, that of a slit of width equal to the diameter of the core; B, that of a slit narrower than the core.

A. *Transmission at a Slit of width equal to the Diameter of the Core of a Tremor-disc.*

Putting I_t for the intensity at the apex of the cone

I_L „ „ core on the level top of truncation

we have $$I_t = I_L \times \frac{r}{r-\gamma}$$

The total quantity of light in the tremor-disc is represented by

$$\tfrac{1}{3} I_L \frac{\pi}{4}(r^2 + r\gamma + \gamma^2)$$

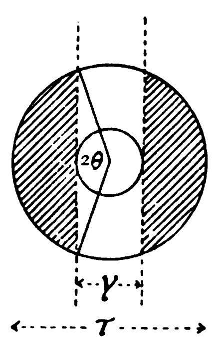


FIG. 6.—Tremor-disc and core on a wide slit.

If the slit of a spectroscope is wide enough to include the whole core of diameter γ we have the quantity of light lost at the slit indicated by the volume of the shaded part of fig. 6; treating this as two pyramids each of height I_L and of base $\frac{1}{4} r^2 (\theta - \cos\theta \sin\theta)$ $= \frac{r^2}{8}(2\theta - \sin 2\theta)$ (an assumption which slightly understates the

have for the quantity of light lost $\frac{1}{3}I_L \frac{r^2}{4}(2\theta - \sin 2\theta)$.

e ratio

$$\frac{\text{tity lost}}{\text{otal}} = \frac{2\theta - \sin 2\theta}{\pi} \cdot \frac{r^2}{r^2 + r\gamma + \gamma^2} \text{ where } \cos\theta = \frac{\gamma}{r}$$

ill be convenient to call the ratio $\frac{\text{transmitted light}}{\text{total}}$ the nission." Numerical values of the transmission are given ollowing table for various values of γ and r. (It must be ered that the transmission values are slightly overstated equence of the approximation used; see, however, below ection on "Slit narrower than the Core.")

TABLE I.

Transmission at a "Core-wide" Slit.

ter of tremor-disc =	2	3	4	5	6	7	8	9	10
sion for $\gamma = 1''$	·78	·60	·48	·40	·34	·30	·27	·24	·22
„ 2		90	·78	·68	·60	·54	48	·44	·40

s with a tremor-disc $5''$ in diameter a slit transmits only cent. of the incident light when the core is $1''$ in diameter,

purposes to take the elementary slice of the frustum at A as having a volume

$$I_L\tfrac{1}{2}(2AC+2AT)dx = I_L(AC+AT)dx$$

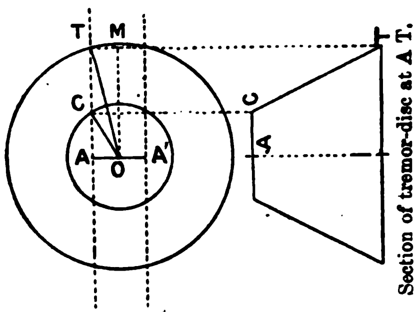


FIG. 7.—Tremor-disc on slit.

OC and OT representing the radii of the core and the tremor-disc. (This value slightly understates the transmission for wide slits.) Now $AC = \left(\frac{\gamma^2}{4}-x^2\right)^{\frac{1}{2}}$ and $AT = \left(\frac{\tau^2}{4}-x^2\right)^{\frac{1}{2}}$

$$\therefore \text{ volume of slice} = I_L\left[\left(\frac{\gamma^2}{4}-x^2\right)^{\frac{1}{2}}+\left(\frac{\tau^2}{4}-x^2\right)^{\frac{1}{2}}\right]dx$$

and the total amount of light transmitted through a slit of width $2x = AA'$ is

$$2I_L\int_0^{AO}\left[\left(\frac{\gamma^2}{4}-x^2\right)^{\frac{1}{2}}+\left(\frac{\tau^2}{4}-x^2\right)^{\frac{1}{2}}\right]dx$$

$$=I_L\left[x\left(\sqrt{\frac{\gamma^2}{4}-x^2}+\sqrt{\frac{\tau^2}{4}-x^2}\right)+\frac{\gamma^2}{4}\sin^{-1}\frac{2x}{\gamma}+\frac{\tau^2}{4}\sin^{-1}\frac{2x}{\tau}\right]_0^{AO}$$

$$\left(\sin^{-1}\frac{2x}{\gamma} = MOC, \text{ and } \sin^{-1}\frac{2x}{\tau} = MOT\right)$$

The whole amount of light in the tremor-disc is

$$\tfrac{1}{3}\frac{\pi}{4}I_L(\tau^2+\tau\gamma+\gamma^2)$$

The ratio $\frac{\text{transmitted light}}{\text{whole}}$ may be, as before, called the "transmission." Numerical values of the transmission are given in the following table for various values of γ and τ. The values are slightly understated for the wider slits in consequence of the

nation used; but a comparison with the values given for e slits in Table I. on page 622 shows that the error is not more than 3 per cent.

TABLE II.

Transmission at a Slit narrower than the Core.

$\gamma = 1''$								$\gamma = 2''$									
·4	·5	·6	·7	·8	·9	1·0	Slit=γ×	1	·2	·3	·4	·5	·6	7	[illegible]	[illegible]	[illegible]
32	·40	·47	·55	·62	·68	·73											
23	·29	·35	·40	·45	·50	·55		·10	·20	·30	·40	·49	·58	·66	·74	[illegible]	[illegible]
18	·22	·27	·31	·35	·39	·43		·08	·16	·24	·32	·40	·47	55	·62	[illegible]	[illegible]
15	·18	·22	·25	·29	·32	·35		·07	·14	·21	·27	·34	·40	·46	·52	·58	[illegible]
								·06	·12	·18	·23	·29	·35	·40	·45	·50	[illegible]
								·05	·10	·15	·21	·25	·30	·35	·39	·44	[illegible]
								·05	·09	·13	·18	·22	·27	·31	·35	·39	[illegible]
								·04	·08	·12	·16	·20	·24	·28	·32	[illegible]	[illegible]
								·04	·07	·11	·15	·18	·22	·25	·29	[illegible]	[illegible]

slit which has a width equal to $\frac{4}{10}$ of the diameter of a = 2″ transmits 27 per cent. of the light incident upon it emor-disc has a diameter 5″.

We have seen that the slit-width may be expressed by the relation

$$s = \frac{2m\lambda f}{a}$$

and that for minimising what we may call diffractional loss of light in the collimator we must arrange that $m \not< 4$.

Now consider a tremor-disc falling on the slit with a diameter of core γ''. For economic use of the light collected by an equatorial the slit must not be much narrower than the core. Let us therefore make the slit "core-wide" and put

$$\frac{F\gamma}{2 \times 10^5} = s = \frac{2m_\gamma \lambda f}{a}$$

where m_γ is the diffractional indicator for a core-wide slit; then, since the ratio A/F for the equatorial is the same as that of the collimator a/f, we reach the result

$$A = \frac{2m_\gamma \lambda \times 2 \times 10^5}{\gamma} \text{ for core-wide slits } \quad \ldots \quad \ldots \quad (6)$$

a relation which gives the aperture of the equatorial suitable for economic and efficient work in terms of the wave-length of light and m and γ. [Thus for spectra to be measured in the region of H_γ, we have, putting $\lambda = 434 \times 10^{-6}\, mm$, and $m = 3$,

$$A = \frac{520}{\gamma}\, mm$$

or, say, twenty inches for $1''$ core of tremor-disc, and 10 inches for $2''$ core of tremor-disc.]

If we wish to use large apertures economically we must adjust m to suit γ. I have summarised matters in Table III.

Table III.

$$A = \frac{17{\cdot}36\, m_\gamma}{\gamma} \text{ for } H_\gamma \text{ and core-wide slit. (A in cms.)}$$

A Cms.	A Inches.	m_γ for $\gamma=1''$.	m_γ for $\gamma=2''$.	A Cms.	A Inches.	m_γ for $\gamma=1''$.	m_γ for $\gamma=2''$.
30	11·8	1·7	3·4	91	35·9	5·2	10·4
63	24·8	3·6	7·2	102	40·2	5·9	11·8
80	31·5	4·6	9·2	150	59·1	8·6	17·2

A small table is added for convenience in converting the diffractional indicator into millimetres for H_γ and for equatorials of various angular apertures.

=	1	2	3	4	5
F	mm	mm	mm	mm	mm
	0·009	0·017	0·026	0·035	0·043
	·013	·026	·039	·052	·065
	·017	·033	·050	·066	·083
	·017	·035	·052	·070	·087

at once obvious that for the economic utilisation of light
s are necessary, and consequently for a given purity of spec-
h values of resolving power are needed in the spectroscope
uatorials of large aperture are used. *It will be observed*
length of collimator under the condition $\frac{a}{f}$ = const. *does*
t the value of m_r. It will be a convenience in considering
stion to introduce the term "collimator intensity" to
the quantity of light per square centimetre on the object-
the collimator. We may then regard the equatorial and
or as a system for producing an intense beam of star
be dealt with by an objective prism camera. It must,
, be remembered that the result $A = \frac{17{\cdot}36 m_r}{\gamma}$ shows that

where $ds/d\lambda$ is the linear dispersion. We shall see below that $\beta = (2m+1)\mathrm{P}\Big/\frac{ds}{d\lambda}$, and for core-wide slits $\beta = (2m_\gamma+1)\mathrm{P}\Big/\frac{ds}{d\lambda}$.

Hence, for resolution of some kind, we must have

$$\frac{\mathrm{A}\gamma}{2\,.\,10^5(2m_\gamma+1)} < \lambda$$

Now we have seen above in equation (6) that $\frac{\mathrm{A}\gamma}{2\,.\,10^5\,.\,2m_\gamma} = \lambda$. Hence the point we have to consider may be put in this form: Is one part in $2m_\gamma$ parts enough to ensure resolution? I shall assume for the moment that it is; for though Wadsworth's observations on resolution with wide slits should be enough for the settlement of the question, his results lead to the idea that with slits as narrow as about $m = 1$ there should be a maximum in the resolution, as the slit is made narrower, and I have not been able to verify the existence of such a maximum in spite of careful search for it. I do, however, find that when R is as large as 78,000 the purity is *at least* as good as that which would be expected from the relation $\mathrm{P} = \mathrm{R}/(2m+1)$ for values up to $m = 3$ and $m = 4$.]

Thus far we have only considered the economical use of the light collected by the object-glass and to be transmitted through the slit, and we have seen how atmospheric disturbances impose upon us the need to use a definite width of slit in stellar spectrography if economy of light is of importance. Let us now proceed to state what are our minimum requirements in the perfection of a photographed spectrum, and then see how we can satisfy them with due regard to economical use of light.

Requirements in Photographed Spectra.—It seems to me not amiss to start with the following statement of requirements in a photographed stellar spectrum:

(1) For the proper identification of lines, a purity of spectrum $\mathrm{P} = \lambda/\delta\lambda$ of at least 10,000 is needed, allowing of distinction between lines for which $\delta\lambda = 0\lambda{\cdot}4$ at $\lambda 4000$, and $0\lambda{\cdot}5$ at $\lambda 5000$. Thus

$$\mathrm{P} = 10{,}000$$

(2) For the proper measurement of wave-lengths, a linear dispersion of at least 1 mm. per 10 tenth-metres is needed. Thus

$$\frac{ds}{d\lambda} = 10^6$$

(3) For the proper discrimination between real stellar lines and faults due to defects in emulsion, a height of spectrum (= length of lines) of at least $0^{\mathrm{mm}}{\cdot}25$ is needed.

$$h' = 0^{\mathrm{mm}}{\cdot}25$$

h respect to (1) we have seen (p. 612) that the purity spectrum is given by the relation $P = R/(2m+1)$, m he diffractional indicator for the slit used, and R the g power of the spectrograph. If we are to utilise the part of the light in a tremor-disc, we must have $/2m_{,}+1$. Thus Table III. tells us that for a 25-inch object- must be 154,000 to give $P = 10{,}000$ with a core-wide

h respect to (2), viz. the linear dispersion, bearing in hat $R = a\,d\theta/d\lambda$, where a is the linear aperture of the tor, and $d\theta/d\lambda$ is the angular dispersion produced by the ystem, we see that the linear dispersion is

$$\frac{ds}{d\lambda} = f_{\text{cam}} \cdot \frac{d\theta}{d\lambda} = f_{\text{cam}} \cdot \frac{R}{a} = \frac{R}{\beta} = \frac{(2m+1)P}{\beta}$$

angular aperture of camera is

$$\beta = (2m+1)P/\frac{ds}{d\lambda} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

st arrange that β has a practicable magnitude.

h respect to (3), viz. the height of spectrum and the

to the final density by "preparing" the plate for the trailing core.]

Since the performance of different spectrographic installations is to be gauged under the same conditions of constancy of P, $ds/d\lambda$, and h' for every installation, and since these conditions imply that the area of the resulting photographed spectrum, viz. $h' \times (\lambda_1 - \lambda_2) ds/d\lambda$, is to be the same in every case, the efficiencies of the installations in the given conditions may be compared by comparison of the intensities attained by a given exposure. We may therefore for the moment leave dispersion out of account provided we allow for any alteration that may be brought about by the use of different prism-systems in the transmission of light. We may denote by $\rho\Pi$ the transmission of the prism-system, where ρ is the factor relating to the light that escapes reflexion at the prism-surfaces, and Π is the factor relating to the light that escapes absorption inside the prisms; and for the moment we will assume that Π sufficiently nearly represents the transmission if it has the value corresponding to a plate of glass of thickness equal to half the total base of the prism-system (I revert to this later).

Intensity of Photographed Spectrum with "Core-wide" Slit (P const., $\frac{ds}{d\lambda}$ const., h' const.).—If light of unit intensity from a star falls upon the object-glass of an equatorial of aperture A, the quantity of light transmitted is $\pi A^2 O$, where O is a coefficient of transmission and may be taken from Vogel's table (*Astroph. Jour.* v. 89), modified if need be to take account of the light diverted into the "scatter-disc." The light is collected in a tremor-disc which falls on the slit of the spectroscope. The slit is adjusted so as to allow the whole core of the tremor-disc to pass. The slit-transmission S_γ under these circumstances may be taken from Table II. above (page 624).

The collimator of aperture a (under the usual condition $\frac{A}{F} = \frac{a}{f_{\text{coll}}}$) transmits $\pi A^2 O S_\gamma$, and $\frac{\pi A^2 O S_\gamma}{\pi a^2} = \frac{A^2 O S_\gamma}{a^2}$ is the "collimator intensity," it being understood that the slit has a diffractional indicator m_γ appropriate to A (Table III., page 625).

The collimator intensity is $\rho\Pi$-fold by the passage through the prism-system; and thus the intensity of the light incident on the object-glass of the camera is

$$\frac{A^2 O S_\gamma \rho \Pi}{a^2} = K$$

In an exposure t the quantity of light $Kt\frac{\pi}{4}a^2$ passes into the camera. If the whole of it were concentrated in the geometrical image of an element of the core-wide slit, of width $\frac{A\gamma}{2 \,.\, 10^5 \,.\, \beta}$

and of height $\dfrac{A\gamma}{2\,.\,10^5\,.\,\beta}$, the average intensity in the image would be

$$Kt\frac{\pi}{4}a^2\,.\,\frac{4\,.\,10^{10}\,.\,\beta^2}{A^2\gamma^2}$$

But we wish to produce a slit-image of which the height is h' on the photograph; therefore we must let the tremor-disc trail on the slit for a time, which is $\dfrac{h'\beta\,.\,2\,.\,10^5}{A\gamma}$ times as long as the exposure needed to give a stationary image of the core with the required density. Or if we give the same exposure in both cases, the intensity with trail is reduced $\dfrac{h'\beta\,.\,2\,.\,10^5}{A\gamma}$-fold. [The circular image of the core is here allowed to trail along the length of the core-wide slit; the result will be that the intensity is greatest along the central line of the slit, and falls off on either side of it; and this uneven though symmetrical distribution will be emphasised rather than diminished by the light in the outlying parts of the tremor-disc. We shall have an increase in the effective purity in the spectrum, but this is a refinement beyond my present purpose.]

Hence, for a spectrum of height h' to be obtained in a given time, the intensity will be

$$A^2OS_\gamma\,.\,\rho\Pi\,.\,\frac{\pi}{4}\frac{\beta\,.\,2\,.\,10^5}{A\gamma\,.\,h'}$$

Remembering equation (7) page 628, viz. $\beta = (2m_\gamma+1)P\Big/\dfrac{ds}{d\lambda}$

and also equation (6), page 625, viz. $2m_\gamma\lambda = \dfrac{A\gamma}{2\,.\,10^5}$

we get for core-wide slits (h' const. in a given exposure)

$$\text{the intensity} = A^2OS_\gamma\,.\,\rho\Pi\,.\,\frac{\pi}{4}\frac{(2m_\gamma+1)P}{h'.\dfrac{ds}{d\lambda}\,.\,2m_\gamma\lambda} \quad \dots \quad (9)$$

For even a 25-inch object-glass $2m_\gamma = 14{\cdot}4$; hence $\dfrac{2m_\gamma+1}{2m_\gamma}$ differs little (7 per cent.) from unity, and approaches more nearly to unity the larger the aperture of the equatorial. Therefore for a comparison of large installations we have to deal with the value of $A^2OS_\gamma\,.\,\rho\Pi$, the other factors being arbitrary constants. Now with regard to the prism-transmission, which is represented by $\rho\Pi$, we must bear in mind that

$$R = (t_2-t_1)\frac{d\mu}{d\lambda} = 2Na\frac{\tan i}{\mu}\;\frac{d\mu}{d\lambda}$$

and hence $\frac{1}{2}(t_2-t_1)$, or the mean thickness of glass traversed in

the prism-system, is equal to $Na\dfrac{\tan i}{\mu}$, if N prisms are used to transmit a collimated beam of diameter a; and if the prisms are all of such angle that the reflected light is wholly polarised, then $\tan i = \mu$, and $\frac{1}{2}(t_2 - t_1) = Na$. Under these circumstances ρ approaches to the value $\frac{1}{2}$ as N increases (for 3 prisms it is about ·65 for $\mu = 1{\cdot}6$); and $\Pi = \alpha^{Na}$, where α is the coefficient of transmission for the material used for the prisms. Again $R = (2m_\gamma + 1)P$, which differs but slightly from $2m_\gamma P$ or $\dfrac{A\gamma}{2\,.\,10^5\lambda}\,.\,P$, when $2m_\gamma$ is large. Therefore for polarising prisms ($\tan i = \mu$) we have

$$R = 2Na\frac{d\mu}{d\lambda} = \frac{A\gamma}{2\,.\,10^5\lambda}\;P$$

and we may put $Na = kA$.

Hence we may write

$$A^2OS_\gamma\rho\Pi = A^2OS_\gamma\rho\alpha^{kA}$$

Before discussing this with a view to finding the value of A which gives the maximum value of intensity on the photograph, it will be well to consider the case of slits narrower than the core of the tremor-disc. I would only point out, with regard to an increase of power of the spectrograph, that if with $Na = kA$ we keep N constant (as is desirable when we have chosen N so as to give the convenient deviation of the beam) then we get the desired increase in Na by increase of a, and a corresponding increase in the size of the prisms.

Intensity of a Photographed Spectrum with Slit narrower than the Core (P const., $\dfrac{ds}{d\lambda}$ const., h' const.).—Suppose the slit allows only part of the core to pass, say $\sigma = n\gamma$, n being less than unity; then the linear width of the slit is

$$s_{n\gamma} = \frac{F\,.\,n\gamma}{2\,.\,10^5} = \frac{2nm_\gamma F}{A} = \frac{2m_{n\gamma}F}{A}$$

and it is clear that $m_{n\gamma} = nm_\gamma$.

The collimator intensity is now $\dfrac{A^2OS_{n\gamma}}{a^2}$ with a diffractional indicator nm_γ.

The intensity on the camera lens is now $\dfrac{A^2OS_{n\gamma}\,.\,\rho'\Pi'}{a^2} = K'$. The geometrical image of an element of the slit has now a height $\dfrac{A\gamma}{2\,.\,10^5\,.\,\beta'}$ and a width $\dfrac{An\gamma}{2\,.\,10^5\,.\,\beta'}$. If we wish the height of the spectrum to be h' as before the star must trail for a time $\dfrac{h'\beta'\,.\,2\,.\,10^5}{\gamma A}$.

now have for the camera

$$\beta' = (2nm_\gamma + 1)\mathrm{P} \Big/ \frac{ds}{d\lambda}$$

for slits narrower than the core (h' const. in a given
e), the intensity is

$$\mathrm{A}^2\mathrm{OS}_{n\gamma} \,.\, \rho'\Pi' \,.\, \frac{\pi}{4} \frac{(2nm_\gamma + 1)\mathrm{P}}{h' \,.\, \dfrac{ds}{d\lambda} \,.\, 2nm_\gamma\lambda} \qquad \ldots \qquad \ldots \qquad 10)$$

ear that this expression gives, when $n = 1$, the value
ntensity for a core-wide slit, and it agrees as it should
e expression (9, page 630) previously got.
may therefore take as the expression for the intensity of
graphed spectrum under the specified conditions and
ions

$$\mathrm{A}^2\mathrm{OS}_{n\gamma} \,.\, \rho a^{\frac{(2nm_\gamma + 1)\mathrm{P}}{2\frac{d\mu}{d\lambda}}} \,.\, \frac{\pi}{4} \,.\, \frac{(2nm_\gamma + 1)\mathrm{P}}{h' \dfrac{ds}{d\lambda} 2nm_\gamma\lambda}$$

Table IV.

Relative Intensities of Spectra given by Various Installations.

trum near H_γ. Purity = 10^4, $\frac{ds}{d\lambda} = 10^6$, $h' = \frac{1}{4}$ mm. Prisms of Jena glass O. 102. Core-wide slit. Tremor-disc $\tau = 5''$, core $\gamma = 2''$.)

re. nches.)	$m\gamma$.	A^2.	O.	$S\gamma$.	$\Pi(O\cdot 102)$.	$\frac{2m\gamma+1}{2m\gamma}$.	Photo-graphic In-tensity.	β.	R.
12)	3·4	900	·64	·63	·450	1·15	189	·078	78000
	5·8	2500	·57	·63	·278	1·09	271	·126	126000
25)	7·2	3969	·53	·63	·208	1·07	294	·154	154000
	8·1	4900	·50	·63	·170	1·06	278	·172	172000
31½)	9·2	6400	·47	·63	·138	1·05	275	·194	194000
(36)	10·4	8281	·44	·63	·108	1·05	260	·218	218000
(40)	11·8	10404	·40	·63	·086	1·04	234	·246	246000

calculating O from Vogel's table (*Astroph. Jour.* v. 89) I have allowed diversion of a certain percentage of the light out of the tremor-disc into catter disc, on the scale of 1 per cent. for every 10 cm. in the aperture. e last columns of the table I have entered β and R. Under the assumed tions of purity and linear dispersion, we have $\beta = \frac{2m_\gamma + 1}{100}$, and $\beta \times 10^6$.

Ve thus see how destructive is the effect of absorption in the n-systems when we try to utilise 63 per cent. of the light wn by the equatorial on the slit. We have already reached urning-point of advantage to be gained from large aperture r these conditions when we have arrived at a 25-inch object-. We must narrow the slit and put up with smaller slit-smission in order to attain greater prism-transmission, or else r our standards in the photographs.

Table V. shows the relative intensities for different installa- with the slit adjusted to include various fractions ·2, . . . 1·0) of the core ($\gamma = 2''$) of the tremor-disc 5″), when the spectrograph in each individual case is gned to give purity = 10^4, $ds/d\lambda = 10^6$, $h' = \frac{1}{4}$ mm. No vance has been made in this table for diffractional losses in the mator ; the reader may allow for it in cases where nm_γ falls w 3, on a scale not differing much from the following, which ve based on Moore's observations (*Astroph. Jour.* xx. 289).

for $nm_\gamma = 1$, the diffractional loss is 30 per cent.
" " = 2 " " " " 20 " "
" " = 3 " " " " 13 " "
" " = 4 " " " " 7 " "

TABLE V.

Relative Intensities of Spectra given by Various Installations.

rum near H_γ. Purity = 104, $ds/d\lambda = 10^6$, $h' = \frac{1}{4}$ mm. Prisms of g angle and of Jena glass O. 102. Tremor-disc $\tau = 5''$, core $\gamma = 2''$.)

es.)	$m\gamma$.	$n =$ ·1. $Sn\gamma =$ ·07.	·2. ·14.	·3. ·21.	·4. ·27.	·5. ·34.	·6. ·40.	·7. ·46.	·8. ·52.	·9. ·58.	1·0. [illegible]
)	3·4	83	108	134	146	161	171	177	186	190	189
						B				3·1	
	5·8										271
)	7·2	197	266	315	332	352	348	340	335	315	294
					C	3·6					
	8·1										278
½)	9·2	245	335	380	388	401	387	367	335	305	274
			P			4·6					
)	10·4										260
)	11·8	308	401	438	426	419	376	333	271	263	234
				3·5	Y						

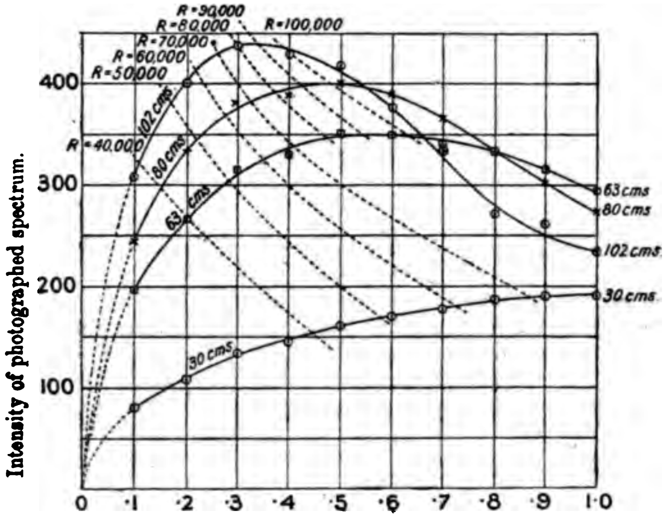
the above table n represents the fraction of the core

34 per cent.; and the "grating transmission" G would have to be

$$G = \frac{S_{\cdot 5_7} \times \rho \Pi}{S_{\cdot 8_7}} = \frac{34 \times \frac{1}{2} \times \cdot 431}{54} = \cdot 136 \text{ or, say, } 14 \text{ per cent.}$$

in order to give me a spectrum as bright as that indicated by 352, the maximum attainable by the use of prisms of Jena glass O. 102.

Fig. 8 shows the results of Table V. plotted in graphical form. The dotted lines are drawn through points where the



Slit-width in terms of decimals of the core of the tremor-disc.

Fig. 8.

resolving power (total length of prism base) has the values marked at the top of the lines.

I recognise very fully that in many ways the discussion just given is far from complete. I embarked upon it, partly, in order to show how helpful the diffractional indicator, which probably every spectroscopist has often seen in the way described above, may be in giving one a general view over the subject; and partly in order to attempt to investigate how close we already are to the limits of what can be achieved with prismatic spectrographs attached to large refractors.

I am convinced that a 30-inch reflector, properly combined with a diffraction-grating spectrograph, would give results which would compare favourably with the most powerful existing installations.

It is almost needless for me to add that in refraining from any attempt to compare different installations under different conditions of seeing I have neglected what is probably a very important consideration.

tion of a Four-prism Spectrograph attached to the 25-inch al Refractor (the Newall Telescope) of the Cambridge Obser-ry. By H. F. Newall.

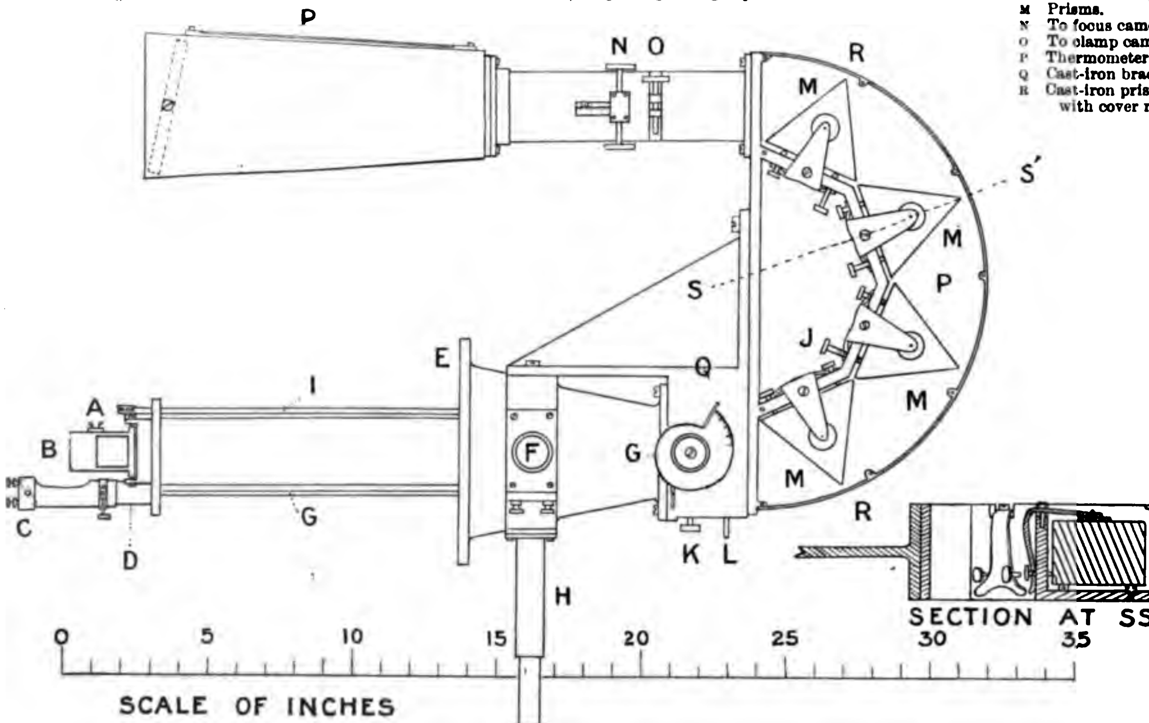
e 1899 July the spectroscopic work at the Cambridge atory has been done with a four-prism spectrograph d to the 25-inch equatorial (the Newall telescope). A of circumstances has stood in the way of the publication description of the instrument. The present note is d to make this good, but it should be stated that the ent described is avowedly of an experimental form which sisted longer than was intended. Inasmuch, however, as derable amount of work has been done with it, and is iscussed with a view to publication, it seems desirable to a description.

Bruce spectroscope, a single-prism instrument, was con-l in 1895 for use in connexion with the 25-inch equatorial *ly Notices*, vol. lvi. p. 98, and *Astroph. Jour.* vol. iii. p. 266). rm was adopted in the hope that it would be possible with btain photographs of spectra of stars of 4th and higher des, and it was found that stars of the 4th magnitude

A FOUR-PRISM SPECTROGRAPH ATTACHED TO THE NEWALL TELESCOPE

Description of Plate

- A Red lamp to illuminate slit and guiding comb.
- B Comparison prisms.
- C Mirror to reflect light into guiding eyepiece.
- D Plane through slit.
- E Flange by which spectroscope is attached to equatorial.
- F Tube to which are fitted the apparatus for comparison spectra.
- G To move guiding comb in front of slit.
- H To view slit, for guiding during exposure.
- I To widen slit.
- J To adjust prism.
- K To focus collimator.
- L To move comparison prisms.
- M Prisms.
- N To focus camera.
- O To clamp camera.
- P Thermometer.
- Q Cast-iron bracket.
- R Cast-iron prism box, with cover removed.



used makes it possible with faint stars to widen the slit; the serious losses which arise in the collimator by reason of the diffractional spread of the beam are thus in great measure avoided. One can overcome the difficulties of identification of lines by utilising the knowledge gained in the study of the spectra of bright stars with both wide and narrow slits.

Plates 18 and 19 represent the four-prism spectrograph, and by comparison with the figure of the Bruce spectrograph (*Monthly Notices*, vol. lvi. plate 10, p. 100) it will be seen that the mode of attachment to the equatorial is the same as for the single-prism instrument; the change consists in the substitution of a train of four prisms held in a strong cast-iron box, R, of semicircular outline in ground plan. This prism box is attached by a strong cast-iron bracket, Q, to the heavy conical casting of gun-metal referred to in *Monthly Notices*, vol. lvi. p. 102, as the framework of the spectroscope. The work has been carried out by the Cambridge Scientific Instrument Company.

The Equatorial and the Correcting Lens.

The 25-inch (63 cm.) equatorial has a focal length of 29 feet (8·84 m.). A simple convexo-concave lens of dense flint-glass, of aperture 5 inches (12·7 cm.) and of focal length 154 inches (391·0 cm.) for light of wave-length 5890–6, is inserted in the convergent beam of rays coming from the object-glass of the equatorial at a distance of about 62 inches (157·5 cm.) from the focus. The corrected focus is nearer to the object-glass by about 18 inches (45·7 cm.). The effective focal length of the combination is about 20½ feet (6·30 m.); the corrected pencil has a ratio 1 : 10, instead of the ratio 1 : 14·0 for the object-glass alone. The corrected focus is thus drawn up inside the tube of the refractor, and the collimator of the spectrograph is pushed up partly into the tube, so that the slit coincides with the corrected focus. [For some further details with regard to the correcting lens see *Monthly Notices*, vol. lvi. p. 101.]

The spectrograph is attached to the equatorial by four thumb-screws passing through the flange E of the conical gun-metal casting. The actual process of mounting the spectrograph is very easily carried out when the refractor is pointed to the zenith.

The Collimator, and Slit, and Guiding Comb.

The collimator has a focal length of 20½ inches [520 mm.] and an aperture of 2⅛ inches [54 mm.]. The effective aperture is 52 mm. with a ratio of 1 : 10.

The slit is made after the device of Sir W. Huggins; the jaws are made of speculum metal with the front surface polished. Special care was taken to work the sharp edges in the proper manner.

uiding comb is placed close to the slit and in front of it; sts of a piece of thin copper foil blackened and shaped so ve three bars or teeth which project across the slit and light from entering. It is provided with mechanism cam G, &c.) for moving it through a small range along . For stellar work, only two of the teeth are used. The re each twice as wide as the interval between them l = $0^{mm}\cdot25$; teeth $0^{mm}\cdot5$). With this arrangement and ifferent settings of the comb nine spectra can be set side on the photographic plate; of these the five central ow no overlap or superposition of spectra, whilst the two nes above and below may under certain circumstances of nages on the slit require special treatment to avoid overlap. t and guiding comb can be viewed, as from in front, by a of mirrors and lenses which enable the observer to see the star or the comparison spark on the slit throughout osures.

ve for years past adopted the method of adjusting the lth by the diffractional method which I have described in r paper (page 609). The following table gives the relation n the diffractional indicator and the actual slit-width in tres :

bservatory, and here described, though I have reason to believe hat the prism system is in reality considerably less absorbent han is there assumed. (It is, in fact, of dense flint, whereas it s there assumed to be extra dense.)

The Prism-box and Prisms.

The foundation on which the four prisms are fixed is a trong iron casting in no part less than 8 mm. thick. It is f very rigid construction, as may be inferred from Plate 19, here it is indicated in ground plan and also in section. The risms are pressed each by a springy clip against three bosses ising from the flat cast-iron table on which they are adjusted. t was found by experiment that the coefficient of friction etween the surfaces of the bosses and the ground surface of he glass prisms was nearly doubled when the bosses were lightly usted over with fine emery. By the adoption of this plan a nuch lighter pressure of the clips is needed to keep the prisms ixed in position.

The prisms were worked by Hilger, all four prisms being cut ut of one block of glass obtained from Jena. The angles are espectively: (1) 56° 12′, (2) 56° 4′, (3) 56° 10′, (4) 56° 11′. The prisms produce a total deviation of 180° for H_γ, when they re set to produce minimum deviation of H_γ. The refractive ndices and specific gravity were determined for the prisms Nos. 1 and 2, and were found to be as follows (trustworthy to wo units in the last place):

μ_D	$\mu_{H\beta}$	$\mu_{H\gamma}$	Sp. Gr
1·6180	1·6297	1·6402	3·598

In Messrs. Schott's list of Jena glasses I find the following lense flint glasses:

O. 167	1·6169	1·6290	1·6393	3·60
O. 103	1·6202	1·6324	1·6428	3·63
O. 93	1·6245	1·6369	1·6475	3·68

nd in the absence of definite information I assume that the risms are made of Jena glass O. 167. It is a transparent glass, ery slightly yellow—a point of considerable importance when our prisms, each having a base $7\frac{1}{2}$ cm. long (total base = 30·8 cm. or 12 inches), are to be used in a stellar spectrograph.

The relation connecting refractive index and wave-length in he form $\mu = a + b\lambda^{-2} + c\lambda^{-4}$

ives, for the values found here experimentally,

$$\mu = 1{\cdot}5983 + 0{\cdot}56 \times 10^{-10}\lambda^{-2} + 4{\cdot}33 \times 10^{-20}\lambda^{-4}$$

expressed in centimetres

$$\frac{d\mu}{d\lambda} = 2490$$

he values given in the Jena list are taken, $\frac{d\mu}{d\lambda} = 2390\cdot0$.]

ord Rayleigh's notation the resolving power is

$$R = (t_1 - t_2)\frac{d\mu}{d\lambda}$$

ing the difference in the thickness of glass traversed on sides of the beam, or the effective total length of base of m-system. The base in the present case is

$$t_1 - t_2 = 4\left(2 \times \text{aperture of beam} \times \sec i \sin\frac{a}{2}\right)$$

the angle of the prisms and i the incidence of the beam prism-surface. For the present purposes we may take n-angle as 56° 9′ and incidence as 50° 31′ for H_γ for sm, and we have

$$t_1 - t_2 = 4(2 \times 5\cdot2 \sec (50° 31') \sin (28° 4'\cdot5))$$

or four. I decided upon four, for reasons which are summarised in the following tables, the condition of a deviation of H_γ through 180° being accepted as essential on account of mechanical arrangements:

	Refracting Angle of each Prism.	Relative Dispersion.	Length of Base for 2-inch Beam.	Total Base.
	° ′		In.	In.
4 prisms	56 0	2·95	2·96	12·0
3 prisms	64 32	3·33	4·44	13·5

Loss by reflexion at the surfaces of the prisms :—

	Losses.		Transmission.								
	$\left(\frac{\sin(i-r)}{\sin(i+r)}\right)^2$	$\left(\frac{\tan(i-r)}{\tan(i+r)}\right)^2$	1 surface. sin.	tan.	2 surfaces. sin.	tan.	6 surfaces. sin.	tan.	8 surfaces. sin.	tan.	Total. %
prisms	·153	·007	85	99	72	98			27	92	60
prisms	·237	·015	76	98	58	97	19	91			55

The tables showed a very even balance, and the fact that in he three-prism arrangement the axes of collimator and camera vould be more widely separated than in the other was of no importance. The casting vote was given for four prisms, on the ground hat there should be want of homogeneity between the top and he bottom of the slab; then, since the prisms were all to be cut n one way from the slab, it would be safer to have an even umber of prisms than an odd, so that two might be turned ipside down relatively to the others. In the event, no such vant of homogeneity was found to exist. The surfaces of the risms are also excellent.

The four prisms described above are used when the spectrum n the neighbourhood of H_γ is photographed. I have used nstead of the fourth prism another prism of larger deviating ower, so that when the train is readjusted to produce minimum eviation of the D lines the instrument is available for photoraphing the green part of the spectrum between D and H_β.

The Cameras.

Three cameras are provided :

(1) a telephotographic combination specially constructed by Dallmeyer, arranged so that the effective focal length is 40 inches (1016 mm.) and the effective ratio is 1 : 20.

(2) a medium camera of focal length 20 inches (508 mm.) and of the effective ratio 1 : 10.

(3) a short camera of focal length 14 inches (356 mm.), and of the effective ratio 1 : 7.

The longest camera was used in the researches on the specum of *Capella* (*Monthly Notices*, vol. lx. p. 418) and of *α Persei Monthly Notices*, vol. lxi. p. 12, and vol. lxii. p. 124). The edium camera has been used in determining the velocity of lected stars (*Monthly Notices*, vol. lxii. p. 296). The shortest

has been used for faint stars; some of the results obtained are given at the end of this note.
ographed spectra obtained with the four-prism spectro-
e numbered in a series F with a suffix to denote the
Thus Fl indicates long camera, Fm medium camera,
camera.
scale of the photographed spectra and the values of a
rn of the micrometer screw expressed in terms of velocity
llows :

ength.	Tenth-metres per mm.	Velocity km/sec per turn of Micrometer.	
50	6·2	44	with the long camera (series Fl)
00	6·7	47	
50	7·2	49	
00	12·2	87	with the medium camera (series Fm)
50	13·1	92	
00	13·9	97	
50	14·7	101	
00	15·6	106	
00	19·5	139	

nately to transmit (*a*) the part of the beam that passes through the thick part of the prisms and (*b*) the part that passes through the thin part of the prisms; the photograph thus taken shows what we may call a "thick" spectrum between two "thin" spectra. It is of course necessary to use exposures about four times as long as when the whole aperture is used. If at the part of the spectrum which we desire to use for measurement there is no shift of the lines in the "thick" relatively to the "thin," then the setting of the collimator is correct. (iii.) If, however, there is a shift, then the focus of the collimator is altered, so that its reading is, let us say, 11·0; and with full beam the camera is refocussed by another set of photographs, and is adjusted to that reading which gives the best definition, let us say 15·4. (iv.) Then a "thick and thin" photograph is taken. Thus by a succession of trials the correct readings of collimator and camera are found.

It will be seen on comparing the photographs that whenever shift is found in the "thick and thin" exposures the lines are sharper in both the "thick" and the "thin" than they are with whole aperture; and herein lies the value of the method, which allows us to find that adjustment of the instrument, for which all parts of the transmitted beam, whether they have passed through the thick and more absorbent part of the prism system or through the thin, come to a focus at the same spot on the photograph.

It will happen, as I have actually found it, that if for one of the prisms is substituted another prism which is either more or less defective than the one eliminated, the definition seems to have deteriorated; and photographs may exhibit a shift of "thick" relative to "thin," which was not present previously for those readings of collimator and camera; but unless the defect is serious, it will be possible to find a new reading of the collimator which, when the camera has been focussed with whole aperture to give the best definition, will not exhibit a shift of "thick" relative to "thin." Thus defects in one part in the system may be mitigated by what may be described as intentional maladjustment in another part. As I have indicated above, a great part of the value of the method lies in the fact that it is essentially empirical.

The shifts in the lines of the "thick" and the "thin" spectra for various collimator readings afford good evidence of the perfection or imperfection of the chromatic corrections of the collimator. And, as regards the transparency of the prism system, it may be mentioned that the exposures needed to give equal intensities at H_γ in "thick" and "thin" photographs are in the ratio of 6 : 5.

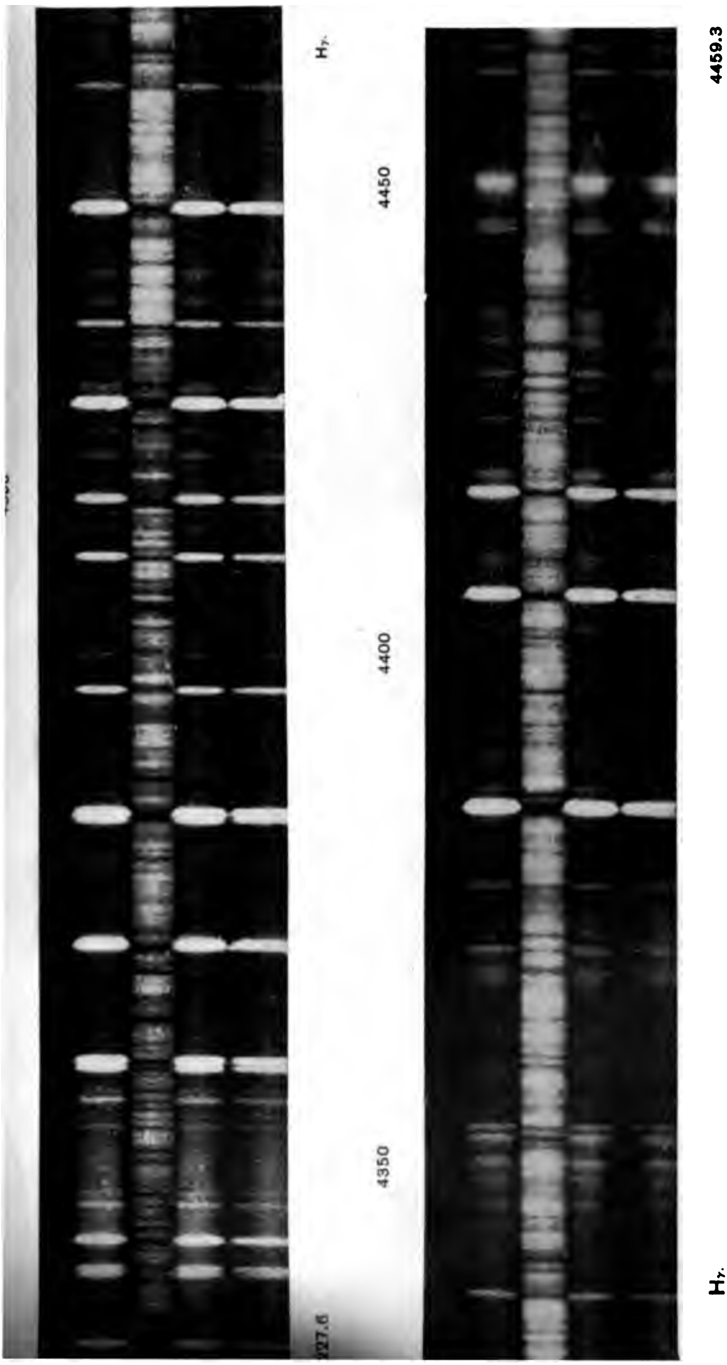
Mode of the Measurement and Reduction of the Photographs.

The photographs are measured on a Zeiss comparator, to which reference is made below, and for which a table of corrections for graduation errors is given. The plates are measured in two positions, (i.) with the spectrum so placed that the red is on the right hand (R to *r*); (ii.) with the plate reversed and the

n "red to left" (R to l). In the position "red to righ
e readings increase with increasing wave-lengths. Sca
ons are then applied. For a few plates the measur
and R to l, were separately reduced to wave-lengths l
e to three chosen lines in the iron comparison spectru
results for each line were combined. For the reductio
-known Hartmann-Cornu relation was used. No attem
n made to smooth the values of the wave-lengt
luced, by taking more lines in the comparison spectru
e three chosen lines; and in no case has a wave-leng
t by extrapolation. The reduction is done with the he
unsviga calculating machine.

en three or more plates of one and the same star ha
us measured—the same lines having as far as possib
cked out in each case by identification with the help of
enlargement on bromide paper—and when the wav
have been deduced, then, assuming constant velocity
, a correction for the Earth's orbital motion is applied
ave-length in the star spectrum, and thus these wav
are left affected only with the velocity of the star.

different values for each line are combined to form
and this mean is used, in comparison with Rowlan
ave-lengths, to identify, if possible, the origin of th
d line or groups of lines



SPECTRUM OF ARCTURUS, WITH IRON COMPARISON SPECTRUM
(ENLARGEMENT APPROXIMATELY TWENTY-ONE-FOLD

2

4

[redacted]

[redacted]

F 334.	F 334 bis.	F 336.	F 337.	F 338.	F 339.	F 341.	Mean.	R.'s ⊙.	✱ − R.
38	41	38	31	41	41	41	45·387	{422, 520}	−084
89	90	93	88	92	92	87	46·901	996	−095
19	12	25	21	21	23	17	50·197	287	−090
89	90	85	81	88	80	82	50·850	945	−095
40	42	41	41	41		38	54·405	505	−100
92	93	90	82	90	84	90	74·887	958	−071
24	25	19	17	18	22	14	94·200	{204, 301}	−052
90	90	84	78	89	96	83	21·871	961	−090

Having thus picked out the solar lines, $\lambda_{\odot}$, which are to be adopted as of the same origin as those measured in the star spectra λ_{*}, the velocity for each line measured on each photograph is deduced by taking out the shift $\delta\lambda = \lambda_{*} - \lambda_{\odot}$ and multiplying it by $\frac{V}{\lambda_{\odot}}$.

Thus Tables II. and III. show the velocities deduced from each of the stellar lines, the wave-lengths of the lines being there given in the eighth column of Table I. The plate F 334 was measured twice in each position (R to *r*) and (R to *l*) both by myself (N.) and by my assistant, Mr. H. J. Bellamy (B.). These serve to show the consistency that can be obtained by one observer in different measures of the same plate, and also by two different observers. Some details have already been given in a previous note (*Monthly Notices*, vol. lxiii. p. 299) in regard to the accuracy attained in the measurement of photographs taken with this instrument.

In more recent measurements and reductions of the photographs the following procedure is adopted.

Each complete photograph has four spectra—namely, the star spectrum and three iron comparison spectra—side by side on the plate arranged thus, and photographed in the order indicated by the numbers:

3. Comparison spectrum taken after the star.
2. Star spectrum.
1. Comparison spectrum taken before the star.
4. Comparison spectrum taken last of all.

[An enlargement of one of the photographs is given in Plate 20, which has been made by photographically reducing a forty-three-fold enlargement of the original negative. The scale of the spectrum as it appears on Plate 20 is at H_{γ} nearly half that of Rowland's map of the solar spectrum.]

TABLE II.

Bk. LXIII. *α Boötis* 1902. *Measured by N.*

ve-lengths of the lines from which the following veloc
deduced are those given in the eighth column of Table I.)

F 334.		F 334 bis.		F 336.		
7·1	5·7	7·9	2·9	17·9	16·4	20·0
5·7	7·1	5·7	3·6	17·9	15·0	20·0
10·0	7·9	7·1	7·9	18·4	14·3	17·1
9·2	6·4	7·9	4·3	17·1	10·7	17·1
8·6	8·6	10·7	7·9	20·5	16·4	15·7
8·6	3·5	9·9	5·7	14·8	13·4	13·4
8·5	1·4	9·2	2·1	18·4	14·1	14·1
4·9	5·6	8·5	7·1	19·1	16·3	15·5
9·9	7·1	10·6	7·1	16·2	12·0	13·4
5·6	3·5	7·8	3·5	16·2	12·0	16·9
10·6	8·4	10·6	9·1	19·0	14·0	13·4
14·0	9·1	14·7	9·1	18·9	13·3	15·4
10·4	4·9	10·4	4·9	15·3	9·0	10·4

Table III.

Bk. LXII. *α Boötis.* *Measured by B.*

	F 334.		F 334 bis.		F 336.		F 337.	
	7·9	4·3	8·6	4·3	14·3	10·7	20·0	16·4
	8·6	1·4	7·9	2·9	16·4	14·3	...	...
	7·1	5·0	7·1	7·1	15·0	15·7	15·7	15·7
	6·4	5·0	8·5	7·1	14·9	14·2	14·9	10·7
	4·3	5·7	7·8	5·7	17·8	17·1	14·2	14·2
	7·1	4·9	4·9	3·5	15·6	14·1	17·0	10·6
	7·1	3·5	5·6	1·4	13·4	15·5	15·5	15·5
	6·4	7·1	9·9	6·4	16·2	12·7	16·9	11·3
	4·9	4·9	6·4	2·8	11·3	11·3	16·2	12·0
	3·5	3·5	1·4	3·5	10·6	12·0	16·2	11·3
	9·1	8·4	7·7	7·0	13·3	14·7	...	...
	11·2	10·5	8·4	9·8	13·3	15·4	...	...
	9·0	8·3	...	...	...	...	...	...
Mean R to *r*	+ 7·07		+ 6·97		+ 14·55		+ 16·29	
Mean R to *l*		+ 5·53		+ 5·05		+ 13·83		+ 13·04
Mean for plate ...	+ 6·30		+ 6·01		+ 14·18		+ 14·16	
Earth's orbital velocity	− 12·14		− 12·14		− 20·60		− 20·62	
Earth's diurnal ...	− 0·14		− 0·14		− 0·21		− 0·26	
Curvature correction	− 0·36		− 0·36		− 0·36		− 0·36	
	− 6·34		− 6·63		− 6·99		− 6·58	
	− 6·48							

that the micrometer wire can be set parallel to the long line; this latter adjustment is not satisfactorily attainable with the short lines in either 1 or 3, for they are not more than ¼ mm. long.

Then the measurements are taken of the chosen lines in the iron and star spectra. The readings are taken thus: four for each standard line in 1 and 3, and two on each chosen line in the star spectrum; half of these are taken as the spectrum is pushed from right to left ("out"), and the other half as the spectrum is moved back again ("home"), so that the mean of the complete readings for each line may be considered to have been made in the mean state of the measuring instrument and of the observer. This procedure has the advantage that the two settings on each line are more completely independent of each other.

h photograph having been measured in the two positions
and R to *l*, the readings for each line are combined in the
nanner. The Hartmann-Cornu relation is used to find
and *c* from three chosen standard lines in the iron com-
spectrum, and the wave-lengths of the lines in the star
n are deduced and are dealt with as in the example of
s given above.

s Comparator.—The measuring machine with which
ements of the spectra have been made since September
of the smaller form of Zeiss Comparator and is marked
. I received the instrument at the end of March 1900;
ccompanied by a Prüfungsschein issued by the Reichs-
The silver scale is stamped with the reference figure
II. 160.

ny request the instrument was made with the eyepieces
at an angle of 45° to the vertical; the observer is thus
nconstrained position in measuring: this is not the case
struments in which the emergent pencil of light is
. Furthermore, in order to set the wires of the micro-
arallel to the lines of the spectra, and also to measure
inations of such lines in planetary spectra, a special scale
v motion were attached to the upper end of the micro-
rough which the photographs are viewed.

Zeiss) in reversed positions. (2) The intervals between the "ten" marks 0·0, 10·0, 20·0 . . . 100·0 were then compared with a specially ruled interval on glass scale; and the error of each of these marks was so determined. (3) The intervals between the whole millimetre marks 0·0, 1·0, 2·0 . . . 100·0 were measured on the micrometer screw, and the error of each of these marks was so determined. (4) And lastly, the intervals between the successive marks 0·0, 0·2, 0·3 . . . 100·0 were measured on the micrometer screw.

The following table thus represents the corrections to be applied to the micrometer readings for each one of the 500 marks on the silver scale used in settings. The corrections for the "ten" marks 0·0, 10·0, 20·0 . . . and also for the whole millimetre marks are based on my own measurements. The corrections for the $\frac{1}{5}$th-millimetre marks are based on means of separate observations made by myself and my assistant, Mr. A. W. Goatcher, who is now at the Royal Observatory, Cape of Good Hope.

Table of Corrections.

	0	10	20	30	40	50	60	70	80	90
0·0	0	− 8	+ 9	+ 21	+ 22	+ 18	+ 18	+ 12	+ 1	− 4
2	+ 8	+ 9	+ 17	+ 25	+ 37	+ 17	+ 31	+ 19	− 4	+ 1
4	0	+ 6	− 4	+ 11	+ 45	+ 23	+ 29	+ 10	− 6	− 2
6	+ 1	+ 7	+ 4	+ 22	+ 26	+ 17	+ 27	+ 24	− 7	+ 12
8	− 9	+ 9	− 9	+ 11	+ 28	+ 19	+ 21	+ 8	− 10	+ 11
1·0	0	+ 5	+ 7	+ 12	+ 23	+ 20	+ 12	+ 13	− 4	0
2	+ 9	0	− 2	+ 25	+ 30	+ 23	+ 25	+ 11	+ 3	− 1
4	0	+ 1	+ 8	+ 26	+ 42	+ 17	+ 8	+ 11	0	+ 8
6	+ 1	− 5	+ 9	+ 30	+ 29	+ 25	+ 14	+ 16	− 11	− 3
8	+ 1	+ 2	+ 6	+ 16	+ 26	+ 16	+ 7	+ 14	+ 3	− 8
2·0	+ 7	− 3	+ 17	+ 19	+ 27	+ 23	+ 7	+ 15	0	+ 5
2	+ 3	+ 8	+ 21	+ 17	+ 28	+ 32	+ 10	+ 11	+ 2	+ 8
4	+ 3	+ 4	+ 12	+ 4	+ 15	+ 26	+ 6	+ 5	− 4	− 9
6	− 1	+ 4	+ 11	+ 13	+ 25	+ 21	+ 6	+ 7	− 7	− 10
8	+ 7	+ 4	+ 7	+ 22	+ 15	+ 22	− 1	+ 20	+ 2	− 2
3·0	0	0	+ 6	+ 19	+ 19	+ 21	+ 6	+ 17	− 3	− 2
2	+ 11	+ 8	+ 6	+ 25	+ 27	+ 29	+ 26	+ 2	+ 13	− 17
4	+ 10	+ 7	− 9	+ 18	+ 28	+ 36	+ 17	+ 10	+ 15	− 7
6	+ 7	+ 2	0	+ 21	+ 24	+ 38	+ 36	+ 8	+ 10	− 3
8	− 2	+ 2	− 5	+ 21	+ 25	+ 23	+ 16	− 5	+ 9	− 10

Mr. Newall, Four-prism Spectrograph.

0	10	20	30	40	50	60	70
+ 2	+ 4	− 3	+ 11	+ 13	+ 32	+ 4	+ 3
+ 3	+ 10	− 16	+ 16	+ 11	+ 39	+ 5	+ 17
− 2	− 6	− 1	+ 10	+ 2	+ 29	− 2	+ 22
− 6	+ 11	− 5	+ 11	+ 4	+ 24	+ 3	0
− 6	− 6	+ 8	+ 9	+ 2	+ 38	+ 18	+ 8
− 7	+ 2	− 8	− 10	+ 9	+ 31	+ 17	+ 6
− 12	+ 21	+ 17	+ 2	+ 31	+ 31	+ 23	+ 5
− 11	+ 6	+ 11	+ 14	+ 18	+ 35	− 18	− 19
+ 2	+ 11	+ 5	+ 12	+ 31	+ 36	+ 27	+ 12
1	+ 11	− 9	+ 11	+ 32	+ 33	0	− 9
− 12	+ 5	− 2	+ 14	+ 30	+ 19	+ 17	+ 4
− 3	− 5	+ 5	+ 26	+ 30	+ 23	+ 19	+ 6
− 8	− 3	− 11	+ 18	+ 17	+ 21	+ 9	− 9
− 1	+ 1	+ 7	+ 15	+ 12	+ 24	+ 6	+ 3
+ 9	+ 7	− 8	+ 21	+ 21	+ 21	+ 4	− 4
− 12	− 7	+ 5	+ 4	+ 25	+ 23	+ 1	+ 5

Velocity in the Line of Sight. Selected Stars. Cambridge Observatory, II. 1903. By H. F. Newall.

The present note is a second contribution to the plan of co-operation between certain observatories to determine the velocity in the line of sight of selected stars. Since the first contribution (*Monthly Notices*, vol. lxiii. p. 296) no alterations have been made in the instrument, but a fuller description of it than has yet been given is published in the present number of the *Monthly Notices*, p. 636. Fuller details of the measurements will, it is hoped, shortly appear in the *Astrophysical Journal*; only the results of the measurements are given here, together with a summary of the mean velocities of the nine stars dealt with.

The year 1903 was unfavourable for observations; the brighter stars were often accessible only by longer exposures than usual, but the photographs of the spectra of fainter stars could hardly be obtained with the linear dispersion given by the four prisms and the medium camera (focal length 520 mm.). As it was regarded as particularly desirable to get spectra of the fainter stars on the list such as β *Ophiuchi* (Draper Catalogue magnitude at Hγ 4·19), γ *Aquilæ* (D.C.M. 4·66), and γ *Piscium* (D.C.M. 5·03), the shorter camera (Dallmeyer Doublet, focal length 356 mm.), was put on in place of the medium. My assistant, Mr. Bellamy, made the most praiseworthy efforts to secure measurable photographs, and succeeded in getting six photographs of β *Ophiuchi* and γ *Aquilæ*; but the sky was never clear enough to make it worth while to attempt to secure photographs of γ *Piscium*.

The velocities deduced for β *Ophiuchi* and γ *Aquilæ* must be regarded as of inferior weight; for the photographs are weak even compared with those got since (in 1904) with the medium camera.

The measurements have been made under my directions by Mr. Bellamy, illness having prevented me from carrying out my intention of making the measurements in duplicate. I am much indebted to Mr. Bellamy for his continued efforts under circumstances that must have been peculiarly discouraging to him.

In the record of the photographs given below

Fm denotes those taken with the medium camera (520 mm.)
Fs „ „ „ shorter „ (356 mm.)

The velocities deduced in the Fs series seem to be more or less consistently about 2-3 km/sec lower than those deduced in the Fm series. I have not been able to assign a cause for this, and have accordingly given the results as deduced from photographs obtained with all due care. The difference appears also in the case of α *Boötis*, though the results are not given below.

hould be stated that the instrument is not provided with al temperature control, but is only encased in a thick feather cover. As instances of the success of this cover, lowing records are of interest, though the electrical control give results of a different order :

f raph.	Month.	Exposure.	Temperature on case of Prism-box. Beginning of Exposure.	End of Exposure.
		m	°	°
94	Feb.	70	11·7 C.	11·3
13	Mar.	50	4·1	3·9
15	Mar.	120	5·6	4·5
22	Apr.	22	7·0	7·1
25	Apr.	25	7·2	7·1
40	May	70	11·7	11·3
82	July	67	12·0	11·3
87	Aug.	80	16·9	16·0
88	Aug.	75	15·5	15·0
05	Oct.	80	9·8	9·5
25	Nov.	28	6·8	6·5

ate and G.M.T. Mid-exposure.		Expo-sure.	Hour angle.	Slit-width.	Range of Spectrum.	Comp. Spect.	No. of Lines.	Velocity relative to Earth.	Velocity reduced to Sun.	Mean Error.
3.	h m	m		mm.				km/sec.	km/sec.	e_0
t. 5	11 51	32	2 48 E	0·025 (m = 3)	4202–4405	Fe Spk.	14	− 21·18	− 1·85	± 0·84
12	8 39	28	5 30 E	,,	,,	,,	15	− 23·37	− 4·11	± 1·19
21	7 59	28	5 35 E	,,	,,	,,	19	− 18·88	− 4·78	± 1·25
v. 14	12 14	28	0 15 W	,,	,,	,,	16	− 5·81	− 1·95	± 1·03
c. 14	7 18	26	2 42 E	,,	,,	,,	12	+ 2·26	− 7·33	± 0·98
(remeasured)								+ 2·23	− 7·36	± 0·58
03·832							(5 photographs)		− 4·56	p.e. ± 0·71
m. 1903.										
b. 9	8 0	70	2 23 E	0·025 (m = 3)	4202–4326	Fe Spk.	13	+ 16·68	+ 3·04	± 0·68
r. 6	11 50	40	3 5 W	0·017 (m = 2)	,,	,,	13	+ 23·76	+ 0·06	± 0·41
7	12 10	50	3 29 W	,,	,,	,,	14	+ 26·09	+ 1·95	± 0·40
16	8 25	40	0 20 W	,,	,,	,,	12	+ 28·01	+ 1·70	± 0·46
21	10 12	42	2 25 W	,,	,,	,,	13	+ 29·89	+ 2·38	± 0·61
c. 11	11 45	40	2 36 E	0·025 (m = 3)	,,	,,	9	− 14·88	+ 2·61	± 1·62
03·306							(6 photographs)		+ 1·96	p.e. ± 0·29
03.										
r. 4	11 39	22	1 44 E	0·017 (m = 2)	4202–4326	Fe Spk.	14	− 11·71	− 7·25	± 0·58
7	11 0	20	2 11 E	,,	,,	,,	14	− 10·20	− 7·00	± 0·67
8	11 10	20	1 57 E	,,	,,	,,	14	− 9·07	− 6·33	± 0·52
,,	11 57	25	1 10 E	,,	,,	,,	14	− 9·79	− 7·10	± 0·41
20	10 57	23	1 23 E	,,	,,	,,	13	− 3·65	− 6·35	± 1·15
22	12 47	15	0 35 W	,,	,,	,,	13	− 3·10	6·64	± 0·71
24	12 49	22	0 45 W	,,	,,	,,	14	− 1·60	− 6·02	± 0·81
27	11 5	20	0 47 E	,,	,,	,,	14	− 2·89	− 8·43	± 0·61
,,	11 56	21	0 4 W	,,	,,	,,	14	− 1·70	− 7·32	± 0·50
,,	12 53	22	1 1 W	,,	,,	,,	14	− 0·76	− 6·47	+ 0·63
ay 4	11 59	19	0 35 W	,,	,,	,,	12	+ 4·62	− 3·93	± 0·55
7	13 0	14	1 48 W	,,	,,	,,	13	+ 4·79	− 5·02	± 0·62
12	12 27	14	1 34 W	,,	,,	,,	10	+ 6·75	− 5·01	± 0·77
15	12 5	24	1 24 W	,,	,,	,,	14	+ 7·49	− 5·37	± 0·41
20	9 51	17	0 30 E	,,	,,	,,	14	+ 6·03	− 8·46	± 0·79

Star and No. of Plate.	Date and G.M.T. Mid-exposure.		Expo-sure.	Hour-angle.	Slit-width.	Range of Spectrum.	Comp. Spect.	No. of Lines.	Velocity relative to Earth.	Velocity reduced to Sun.
α Boötis, 1903.		h m	m		mm.				km/sec.	km/sec.
Fm 458	May 25	12 52	35	2 48 W	0·017 (m = 2)	4202 4326	Fe Spk.	14	+ 8·31	− 7·7
Fm 461	„ 26	11 13	14	1 15 W	„	„	„	13	+ 11·37	− 4·1
Fm 464	„ 27	9 59	18	0 5 W	„	„	„	14	+ 8·56	− 8·3
Fm 466	June 2	9 44	18	0 14 W	„	„	„	13	+ 10·44	− 8·2
Mean	1903·333								(19 photographs)	− 6·5
β Ophiuchi, 1903.										
Fs 482	July 7	13 18	67	2 38 W	0·025 (m = 3)	4202 4326	Fe Spk.	6	− 7·46	− 16·8
Fs 487	Aug. 4	10 25	80	1 35 W	„	„	„	7	+ 4·43	− 14·8
Mean	1903·551.								(2 photographs)	− 15·8
γ Aquilæ, 1903										
Fm 473	June 22	13 5	70	0 37 E	0·017 (m = 2)	4202 4405	Fe Spk.	7	− 11·37	+ 0·8
Fs 485	July 24	11 45	70	0 44 W	0·025 (m = 3)	„	„	11	− 1·94	− 2·7
Fs 488	Aug. 4	11 50	75	1 34 W	„	„	„	8	+ 3·14	− 2·3
Fs 492	„ 7	11 15	78	1 13 W	„	„	„	10	+ 3·35	− 3·3
Mean	1903·555								(4 photographs)	− 1·8
ε Pegasi, 1903										
Fs 502	Oct. 12	10 30	70	2 13W	0·025 (m = 3)	4260 4405	Fe Spk.	11	+ 23·68	+ 2·7
Fs 505	16	10 5	80	2 2W	„	4202 4405	„	17	+ 27·07	+ 4·9
Fs 512	26	8 40	70	1 18W	„	„	„	16	+ 26·99	+ 2·2
Mean	**1903·795**								(3 photographs)	+ 3·3
ε Leonis, 1903										
Fm 415	Mar. 16	10 50	120	0 44W	0·017 (m = 2)	4202 4326	Fe Spk.	15	+ 21·39	+ 4·4
Fm 434	Apr. 24	12 15	90	4 42W	„	„	„	11	+ 30·12	+ 1·9
Fm 440	May 2	9 20	70	2 19W	„	„	„	9	+ 33·93	+ 5·0
Fm 447	12	9 42	65	3 20W	„	„	„	6	+ 31·30	+ 1·8
Mean	**1903·303**								(4 photographs)	+ 3·3
ε Virginis, 1903										
Fm 444	May 4	13 45	80	3 27W	0·017 (m = 2)	4202 4326	Fe Spk.	12	+ 0·31	− 15·7
Fm 445	7	11 48	76	1 50W	„	„	„	13	+ 2·70	− 13·8
Mean	**1903·342**								(2 photographs)	− 14·7

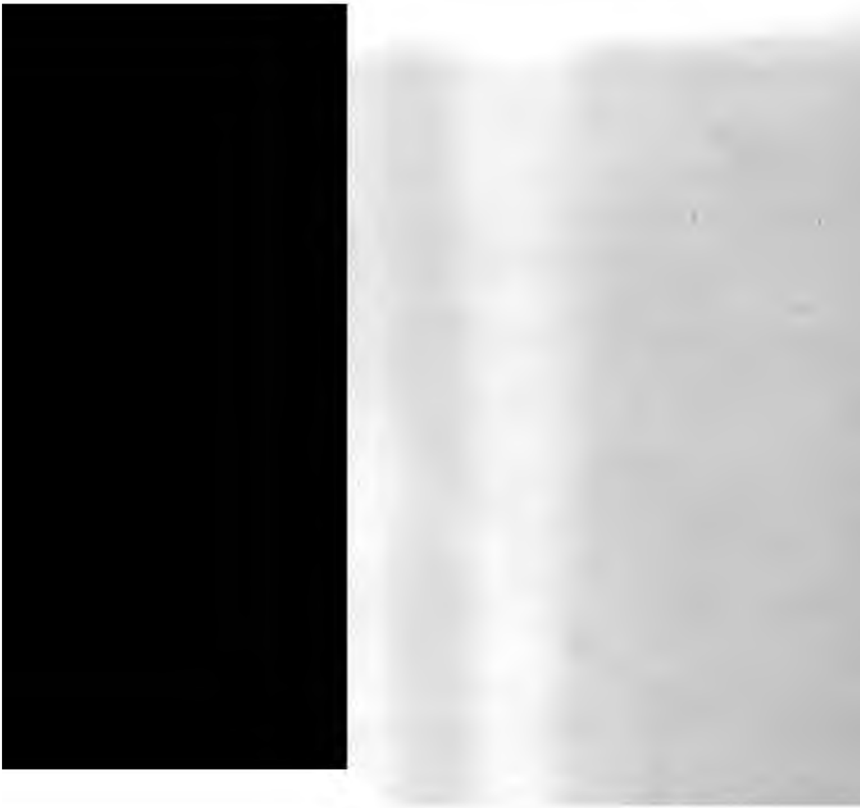
Summary.

Epoch.	Star.	No. of Photographs.	Velocity in Line of Sight.
1903·423	α Arietis	8	− 16·36 ± 0·49
1903·832	α Persei	5	− 4·56 ± 0·71
1903·306	β Geminorum	6	+ 1·96 ± 0·29
1903·333	α Boötis	19	− 6·58 ± 0·22
1903·551	β Ophiuchi	2	− 15·85
1903·555	γ Aquilæ	4	− 1·87
1903·795	ε Pegasi	3	+ 3·30
1903·303	ε Leonis	4	+ 3·34
1903·342	ε Virginis	2	− 14·78

Errata in Mr. Nevill's Paper.

Monthly Notices, vol. lxv. p. 267, first three lines.

For −0·51, −1·01, −1·83
read +0·51, +1·01, +1·83.



MONTHLY NOTICES

OF THE

YAL ASTRONOMICAL SOCIETY.

APPENDIX TO VOL. LXV.

[*From Proceedings of the Royal Society, Vol. LXXIV.*]

With indication of the original pagination.

No. 2.

CONTENTS.

[redacted] The Arc Spectrum of Scandium and its Re
Spectra." By Sir NORMAN LOCKYER, K
F.R.S., and F. E. BAXANDALL, A.R.C.Sc. R
—Read February 9, 1905.

[redacted] Very little has been published regarding the sp
[redacted] ement. The records of Thalen,* and Exner and
[redacted] ly ones previously given, the former observer
[redacted] on to the spark spectrum, whereas Exner and Ha
[redacted] e lines under both arc and spark conditions.
[redacted] owever, no lines are given in the region le
[redacted] 4744·0. Rowland, in his "Tables of Solar Wav
ribes a small number of solar lines to scandiu

gst the rarer elements it apparently stands by itself from this of view. This prominence of scandium lines in some stellar ra, and particularly in the chromospheric spectrum, makes it ıble to give as complete a record of the lines as possible, and also alyse them in relation to their appearance or non-appearance in -terrestrial spectra.

ne time ago Sir William Crookes was good enough to send a le of scandium oxalate, and very good photographs of the arc rum have been obtained with a larger Rowland concave grating, g a ruled surface of $5\frac{3}{4} \times 2$ inches ($14\frac{1}{2} \times 5$ cm.), and a radius of et 6 inches. The scale of the photographs is such that the ıce between K and D is $30\frac{1}{4}$ inches, or 77 cm. This is equivalent 6 tenth-metres per millimetre. The scandium oxalate was tedly impure, and for the purpose of eliminating lines due to rities, the spectrum has been directly compared with the spectra ll the chemical elements available at Kensington, which were graphed under identical instrumental conditions. The chief es of impurity were found to be cerium, thorium and ytterbium. lines of the first two elements were easily eliminated by comon with the Kensington photographs of their respective arc ra. In the case of ytterbium it was a more difficult matter, as is one of the elements not investigated at Kensington. The nation of its lines has, however, been accomplished as far as le, by ascertaining whether there were lines in the scandium graph in the position of the stronger lines of ytterbium as led by Thalen,* and Exner and Haschek.† If such were found the case, and the intensity in the scandium photographs such the line was thought to be due to ytterbium, it was discarded the list of scandium lines.

e fiducial lines used for the reduction of wave-lengths were the d K lines of calcium (which occur as impurity lines in the ium spectrum), and Rowland's solar-scandium lines 3907·62, 55, 4082·59, 4247·00, 4314·25, 4400·56, 4670·59, 5672·05. The idence of these lines was first confirmed by a direct comparison of Kensington photographs of the solar and scandium spectra. In ion to the foregoing, well-marked scandium lines were found to be ly coincident with the isolated solar lines 5031·20, 5239·99, 5527·03, for which Rowland had given no origin. The solar -lengths of these were adopted and used in the reduction of the -lengths of the remaining lines.

e table at the end of the paper gives the residuum of lines after

* Öfversigt k. Vetensk. Akad. Forhandl.' (1881).

† Wellenlängen-Tabellen für Spektralanalytische Untersuchungen auf Grund travioletten Bogenspektren der Elemente,' Leipzig und Wien, Franz-Deuticke.

the elimination of those due to other metals. There can be little doubt that the majority of the lines, except, perhaps, some of the very lowest intensity, really belong to scandium. Exner and Haschek's wave-lengths and intensities of the scandium arc lines are given for comparison.

Scandium Lines in the Solar Spectrum.

Rowland, in his "Tables of Solar Wave-lengths," ascribes a small number of lines to scandium, but a comparison of the Kensington photographs of the arc spectrum of this element with the solar spectrum shows that in addition to these there are other solar lines nearly certainly due to the same element. The table gives the solar lines which, by a careful comparison of the metallic and solar spectra, have been considered to correspond, without any doubt, with scandium lines. In addition to these, there is a considerable number which agree closely in position with weak solar lines, but of their identity there is, perhaps, some doubt. In some cases the solar lines are so weak that it is impossible to establish their identity with scandium lines by direct comparison of the two spectra, the only guide being the close agreement in wave-length, and the relative intensity of the metallic and solar lines. In other cases it is doubtful whether the metallic lines are strong enough to account for the solar lines. In the table these lines are denoted by an asterisk, and must be accepted only provisionally as "possible" scandium-solar lines.

The following analysis of the scandium lines, with reference to their intensities, and their appearance or non-appearance in the solar spectrum, will be of interest.

Intensity (Sc. arc lines).	Total number of Sc. lines.	Number undoubtedly represented in solar spectrum.	Number possibly represented in solar spectrum.	Number apparently absent from solar spectrum.
10	4	4	—	—
9	3	3	—	—
8	7	6	1	—
7	4	3	1	—
6	5	2	1	2
5	7	3	4	—
4	15	6	3	6
3	21	—	5	16
2	28	—	2	26
1	16	—	—	16

It will be seen that of the 23 lines of intensity 6 or greater, 18 occur in the solar spectrum, three others are doubtfully present, while

ppear to be lacking. Of the lines below intensity 6, the great ity are missing from the Fraunhoferic spectrum.

Scandium Lines and the Chromospheric Spectrum.

e scandium lines which occur in the chromospheric spectrum, gh not so numerous as those in the solar spectrum, are of conably greater prominence. The strongest line of scandium at 17·00 is very well developed in the chromosphere, and is, as far as etallic lines are concerned, inferior only to the lines of strontium calcium. Although all the scandium lines represented in the nosphere have high intensities in the scandium arc spectrum, are a few others of equal prominence in the metallic spectrum are either lacking or occur only as quite insignificant lines in the nospheric spectrum.

hromospheric Lines probably due either wholly or partially to Scandium.

mospheric line.		Scandium line.			Remarks.
	Intensity. Max. 10.	λ.	Intensity. Arc. Max. 10.	Intensity. Spark. Max. 10.	
·0	7	4247·00	10	10	Due solely to scandium.
·0	2	4314·25	9	8	,, ,,
·2	5	4320·90	9	6	Probably partially due to *p*Ti 4321·20.
·9	7	4374·65	8	6	Probably partially due to *p*Ti 4374·90.
·9	5–6	4400·56	8	5	Probably partially due to *p*Ti 4399·94.
·8	3–4	4670·59	7	4	Due solely to scandium.
·2	2	5031·20	8	3	,, ,,
·6	6	5527·03	10	7	This chromospheric line is broad and is probably composed of the scandium line and the strong Mg spark line λ 5528·64

Scandium Lines in Sun-Spot Spectra.

tween F and D, the region over which the Kensington observations n-spot spectra extend, there are nine solar lines which have been to be due to scandium, either wholly or partially. Of these, five

st the most widened lines observed during the last 24 years
m, however, have only been recorded a few times. The
ne, λ 5672·047, is a very persistent widened line and is
ys greatly affected. It is, of course, quite possible that
ne in question, although weak, may be a compound one,
additional chemical element is involved in its formation.
her than scandium has been suggested by Rowland, and
e origin has been found for it by reference to Kensington
netals. It must, therefore, be accepted provisionally as
due to scandium.

Scandium Lines in Stellar Spectra.

e probable that, as the stronger scandium lines occur in
ctrum, they also appear in the spectra of stars resembling
h as those of the Aldebarian and Arcturian types. The
the lines in these stars with the dispersion usually employed
ectra makes it difficult to establish definitely whether the
es are really present. At the next higher stage (Polarian,
) those scandium lines previously given as occurring in the

Arc Lines of Scandium.

* = Doubtfully identical with solar lines.

Kensington.		Exner and Haschek.		Corresponding solar lines.		Rowland's origin for solar lines.
λ.	Int. Max. 10.	λ.	Int. Max. 50.	λ.	Int.	
3907·62	10	3907·69	30	3907·62	3	Sc–Fe
11·94	10	12·03	30	11·96	2	Sc
		15·09	1			
		18·36	1			
		23·64	1			
		33·59†	6			
		52·43	1			
		89·18	1			
* 96·75	5	96·79	15	96·68	00	Sc
4014·66	3	4014·68	6			
20·55	8	20·60	20	4020·55	1	Sc
		23·36	1			
23·88	8	23·88	30	23·83	2	Sc
		31·51	2			
34·35	2					
36·98	1					
43·97	2					
46·64	2					
47·97	4—5	47·98	10	47·96	0	—
		50·09	2			
		52·00	1			
* 54·68	3	54·71	10	54·71	00	Sc
		56·72	3			
		67·15	2			
		75·13	2			
		78·70	2			
82·59	6	82·60	15	82·59	3	Fe–Sc–Ti
		86·15	1			
86·67	2—3	86·80	3			
87·26	1	87·28	3			
* 94·85	2—3	95·03	1	94·85	0	—
4106·02	2—3					
33·10	2	4133·10	4			
* 40·42	2—3	40·42	5	4140·40	0	—
41·78	1					
52·50	3	52·51	8			
62·85	1					
63·77	1					
65·38	2—3	65·39	8			
71·47	1—2					
71·98	2—3	71·92	2			
		4218·43	1			
		19·90	1			
4224·32	1					
		25·76	1			
		32·13	1			

† *Possibly masked in Kensington* photograph by K line of Ca.

Arc Lines of Scandium—*continued.*

[K]ensington.		Exner and Haschek.		Corresponding solar lines.	
	Int. Max. 10.	λ.	Int. Max. 50.	λ.	Int.
		4233·83	2		
		37·96	1		
·25	2	38·21	3		
		39·72	1		
		46·27	1		
·00	10	47·02	50	4247·00	5
		51·22	1		
		83·71	1		
		86·71	1		
·91	4—5	94·94	5	94·94	2
·83	4—5	4305·89	8	4305·87	2
·25	9	14·31	30	14·25	3
·90	9	20·98	20	20·91	3
·15	8	25·28	20	25·15	4
·74	3—4	54·79	3	54·78	1
		58·85	1		
		59·25	1		

Arc Lines of Scandium—*continued.*

ington.	Exner and Haschek.		Corresponding solar lines.		Rowland's origin for solar lines.
Int. Max. 10.	λ.	Int. Max. 50.	λ.	Int.	
1—2					
1					
6					
5					
4	—	—	5085 ·67	0	—
3					
2					
2					
2					
3—4					
2					
1					
2—3					
1					
<1					
1					
2					
1					
<1					
2					
2					
5—6	—	—	5239 ·99	1	—
2—3					
1—2					
2					
1					
2					
2					
1					
3					
3—4					
2—3					
1—2					
3					
2					
4					
3—4	—	—	5484 ·85	000	—
4					
4—5	—	—	5520 ·73	00	—
10	—	—	27 ·03	3	—
2					
7	—	—	5658 ·10	2	Y
3—4	—	—	58 ·56	0	—
3—4	—	—	67 ·37	0	—
4	—	—	69 ·26	1	—
9	—	—	72 ·05	0	Sc
4	—	—	84 ·42	1	—
8	—	—	87 ·06	000	—
7	—	—	5700 ·40	00	—
6					
8					

"On the Stellar Line near λ 4686." By Sir NORMAN LOCKYER, K.C.B., LL.D., Sc.D., F.R.S., and F. E. BAXANDALL, A.R.C.Sc. Received January 4,—Read February 9, 1905.

In the publication of the results derived from a study of the Kensington photographic spectra of the 1898 eclipse, it was stated* that a fairly prominent line recorded near λ 4686, for which no terrestrial origin could be found, agreed closely in position with a well-marked line of unknown origin in one of the Kensington photographs of the spectrum from a helium tube. In the helium photograph the position has been recently found from careful measures made on the lines 4120·97, 4388·10, 4713·25, and the line in question, and subsequent use of Hartmann's formula.

The resulting wave-length of the strange line was 4685·97. Similar measurements were made on the eclipse photographs, the fiducial lines used being 4508·5 (*p* Fe), 4584·0 (*p* Fe), and 4713·25 (He). The result gave 4685·90.

The two calculated wave-lengths so nearly agree that it is very probable the line is of identical origin in the two cases. The eclipse line is, moreover, of the same nature as the helium eclipse lines, long and sharply defined. It would therefore seem that the line is due to a gas which is associated in some way with helium. The line, however, only appears in one photograph of the helium spectrum, and whether this is due to the particular sample of helium used, or to some special condition of current which is conducive to the appearance of the strange line, it is impossible to say.

A line near the same position has been recorded by various spectroscopists in different celestial spectra. The following table contains the available records of the line in question :—

Spectrum.	Observer.	λ.
Bright line stars	Campbell	4688
" "	Pickering	4688
" "	McClean	4687 ·5
Nebulæ	Campbell	4687
Orion stars..............	Pickering	4685 ·4
ε Orionis	Lockyer	4687 ·0
Trapezium star (Bond 628)	Keeler	4685 ·4
β Crucis	McClean	4685 ·1
Chromosphere	Evershed	4685 ·7
"	Lockyer	4687 ·0
"	Frost	4685 ·7
"	Lord	4686 ·3
"	Humphreys	4685 ·4
	Mean λ ..	4686 ·4

* 'Phil. Trans.,' A, vol. 197, p. 202.

[redacted]

It will be seen that the mean wave-length is in fairly good accord with that of the unknown terrestrial line 4685·97. The line, however, in the nebular and bright-line-star spectra is broad and ill-defined, and the estimated wave-lengths are probably somewhat uncertain, and not to be depended on so much as those obtained from spectra in which the line is sharply defined. If in seeking the mean wave-length these probably less accurate wave-lengths be excluded, the result is 4685·9, which is in very close agreement with the position of the terrestrial line.

Rydberg has shown that the stellar line near 4686—associated with the new series discovered by Pickering in the spectrum of ζ Puppis—is probably the first line of the principal series furnished by hydrogen. His calculated wave-length value for the line is 4687·88,* which would appear to be about two tenth-metres in error, as the corresponding celestial line probably has, as is shown in the present note, a wave-length near 4685·9.

In the light of this evidence for the probable identity of the terrestrial and stellar lines, it seems desirable to institute further research on the spectrum of helium under varying electrical conditions with the object of possibly obtaining the terrestrial equivalents of the so-called new hydrogen series of ζ Puppis.

DESCRIPTION OF PLATE.

The plate shows a comparison of the spectrum (region 4450 to 4750) of the chromosphere, the helium spectrum containing the line 4686, and that of ζ Orionis (Alnitamian). The identity of position of the helium lines, and 4686, with lines in the chromospheric and stellar spectra is clearly shown. The fainter lines in the helium spectrum are all due to oxygen.

* 'Ast. Phys. Jour.,' vol. 6, p. 237.

"Note on the Spectrum of μ Centauri." By Sir NORMAN LOCKYER, K.C.B., LL.D., Sc.D., F.R.S., and F. E. BAXANDALL, A.R.C.Sc. Received January 4,—Read February 9, 1905.

An investigation of Pickering's reproduction of this spectrum*—which apparently consists of the spectrum of an Orion star + bright hydrogen lines and certain other bright lines of minor intensity—suggested that the latter are radiation lines corresponding to some of the stronger absorption lines of α Cygni. These α Cygni lines have previously been attributed to the enhanced lines of certain metals, chiefly Fe, Ti, Cr, Mg, and Si.

A close investigation has now shown that nearly all the most marked bright lines in μ Centauri—other than those of hydrogen—occupy positions closely corresponding to those of the most conspicuous enhanced lines of iron. The wave-lengths of some of the bright μ Centauri lines are compared with those of the enhanced lines of iron and α Cygni lines in the table at the end of this note. The close agreement is very noticeable.

It is worth while, then, to analyse in detail Pickering's statement in his note† on the μ Centauri spectrum. He states: "Lines 4922·1 and 5015·8 are bright on the edge of greater wave-length." The lines whose wave-lengths he gives are the helium-Orion absorption lines. The only two enhanced iron lines in this region are at λλ 4924·11 and 5018·63, which occupy exactly the positions relatively to the helium lines which Pickering notes as being bright in the μ Centauri spectrum—that is, they border the helium lines on the edge of greater wave-length.

Again, he says: "The two most conspicuous (bright lines) are at wave-lengths 4232 and 4584 approximately." Two of the most marked lines in the α Cygni spectrum are at λλ 4233·25 and 4584·02, and these undoubtedly correspond to the two most conspicuous enhanced lines of iron between H_δ and H_β.

Again. "Line 4387·8 is bright on the edge of shorter wave-length." In α Cygni there is a well-marked line at λ 4385·55, which agrees in position with another enhanced iron line.

Also: "A diffuse bright band appears on the side of shorter wave-length of the dark line 4531·4." There is a distinctive group of α Cygni—enhanced iron lines at λλ 4508·46, 4515·51, 4520·40, 4522·69, which, thrown together into an irresolvable group in μ Centauri, may well correspond to the diffuse line quoted by Pickering.

Further: "The dark line 4553·4 is superposed on a bright band."

* 'Annals Harv. Coll. Obs.,' vol. 28, Part II, Plate 1.

† 'Annals Harv. Coll. Obs.,' vol. 28, Part II, p. 178.

Bright Lines in the Spectrum of μ Centauri.

λ (μ Centauri).	Nature.	Probable origin.	λ of probable origin.	α Cygni. λ.	α Cygni. Intensity (Max. 10).	Remarks.
4171·4 to 4181·4	Bright and broad	p Fe	4173·52	4173·5	6—7	Mean position of Fe double 4176·2, that of the μ Centauri line 4176·4.
			4178·95	4179·0	6—7	
4232 9	Very bright and narrow	p Fe	4233·25	4233·3	8	
4295·7 to 4303·1	Bright but not well-marked	p Fe	4296·65	4296·7	4	Mean position of Fe double 4299·9, that of μ Centauri line 4299·4.
			4303·34	4303·3	5	
4385·0	Bright and narrow	p Fe	4385·55	4385·5	5—6	
4508·9	" "	p Fe	4508·46	4508·5	5	
4515·1	" "	p Fe	4515·51	4515·5	5	
4518·6 to 4527·6	Bright but irresolvable	? p Fe + extra line	4520·40	4520·4	4	Mean position of p Fe double 4521·5, that of μ Centauri line 4523·3.
			4522·69	4522·7	5	
4549·9	Bright and narrow	p Fe	4549·64	4549·8	7	
4556·3	" "	p Fe	4556·06	4556·1	5	
4584·6	Very bright	p Fe	4584·02	4584·0	7	

This bright band may very well correspond to the α Cygni enhanced iron lines 4549·64 and 4556·06 thrown together in the μ Centauri spectrum. It is possible, though, that the dark line 4553·4, quoted by Pickering, is only the dark interspace between the bright 4549·64 and 4556·06 lines.

It may be here remarked that among the brightest lines in the spectra of Novæ at their initial stages are lines agreeing in position with the most marked α Cygni and enhanced Fe lines, and in this way we trace a resemblance between the minor bright lines of μ Centauri and the most conspicuous bright lines—other than those of hydrogen—in the early spectra of Novæ.

Lines corresponding to these bright lines in μ Centauri also occur in the spectrum of γ Cassiopeiæ, but they are far less well-defined in the case of the latter star.

The wave-lengths of the μ Centauri lines given in the table were reduced, by means of Hartmann's formula, from measures made on Pickering's reproduction, the fiducial lines used being 4121·0 (He), H_γ, and H_β.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXV. MAY 12, 1905. No. 7

W. H. MAW, Esq., PRESIDENT, in the Chair.

Scriven Bolton, 24 Kensington Terrace, Hyde Park, Leeds;
Bahne Bonniksen, 16 Norfolk Street, Coventry;
Edwin Turner Cottingham, The Limes, Thrapston;
William George Hooper, Wiverton House, Musters Road, West Bridgford, Nottingham;
Percy Merivale Marshall, Filey House, Livingstone Road, Scarborough; and
Karl Pearson, M.A., LL.B., F.R.S., Professor of Applied Mathematics and Mechanics, University College, London; and 7 Well Road, Hampstead, N.W.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Walter Sidney Adams, M.A., Solar Observatory, Mount Wilson, California, U.S.A. (proposed by G. E. Hale);
Ernest Percival Cotton, Surveyor General and Commissioner of Crown Lands, Lands and Survey Department, Lagos, West Africa (proposed by W. H. Walmsley);
Rev. Alex. C. Henderson, B.D., The Manse, Delting, Brae, Shetland, N.B. (proposed by Rev. J. Spence);
Rev. Frederick John Jervis-Smith, M.A., F.R.S., M.Inst.E.E., University Lecturer in Mechanics and Millard Lecturer in Engineering and Mechanics, Trinity College, Oxford (proposed by H. H. Turner); and
T. Hobart Pritchard, 5 Cotford Road, Thornton Heath, Surrey (proposed by T. W. Brownell).

Sixty-nine presents were announced as having been received since the last meeting, including, amongst others :—

G. Bigourdan, Les Eclipses de Soleil : instructions sommaires sur les observations que l'on peut faire pendant les éclipses, presented by the Author ; map of England showing track of total solar eclipse of 1927, presented by Rev. S. J. Johnson.

On Hansen's Coefficients for the Inequalities in the Moon's Longitude. By E. Nevill.

As I have already stated on several occasions during the last ten years, my own calculations have sufficed to confirm the accuracy of the values given by Hansen in the *Darlegung* for the coefficients of the inequalities in the expression for the Moon's longitude derived from the direct perturbing action of the Sun, the difference being seldom more than a few hundredths of a second of arc.

This statement has now been confirmed by the still more complete calculations of Professor Brown (*Monthly Notices*, vol. lxv. p. 276) ; and it follows that the theoretical expression for the disturbing action of the Sun on the normal elliptic motion of the Moon must be held to have been determined with all requisite accuracy.

The differences between the tabular and theoretical values of the coefficients are not sufficient to produce any important discrepancy between the tabular and observed places, as they will seldom much exceed a second of arc, and be in general much smaller.

Hence the existing large discordances between the tabular and observed places of the Moon must be ascribed to some different origin—to the effect of the perturbations of the planets, the figure of the Earth, or some similar cause.

This result is most important, for it clears the field.

For the sake of comparison I give the results that I have derived, reduced with values of the constants which differ but very slightly from those made use of by Newcomb in his transformation of Hansen's theoretical values. They are the results which have been adopted in my investigation of the errors of Hansen's tables now awaiting printing.

They have been compared with :

1. Hansen's theory.
2. Hansen's tables.
3. Brown's theory as brought up to Hansen's data $=$ B+R.

The notation is Hansen's : the smaller terms have been generally omitted, and the values carried only to two places of decimals.

Argument.	Coefficient.	Correction to reduce to the values of		
		Hansen's Theory.	Hansen's Tables.	Brown's Theory.
g	+ 22640″·15	+″·00	+″·50	+″·00
$2g$	+ 769·06	+ ·00	− ·09	+ ·00
$3g$	+ 36·13	+ ·00	− ·01	− ·01
$4g$	+ 1·94	+ ·00	− ·01	+ ·00
$-3g-g'$	+ ·55	+ ·00	− ·00	+ ·00
$-2g-g'$	+ 7·67	+ ·00	− ·01	+ ·00
$-g-g'$	+ 109·88	+ ·04	+ ·07	+ ·06
$-g'$	+ 669·85	+ ·00	+ ·16	− ·10
$g-g'$	+ 148·28	− ·26*	− ·25	− ·22
$2g-g'$	+ 9·72	+ ·00	+ ·00	+ ·01
$3g-g'$	+ ·67	+ ·00	+ ·00	+ ·01
$-g-2g'$	+ 1·17	+ ·01	+ ·01	+ ·00
$-2g'$	+ 7·50	+ ·01	+ ·02	+ ·03
$g-2g'$	+ 2·58	+ ·01	− ·01	+ ·02
$2g-2g'$	+ ·19	+ ·00	+ ·00	+ ·01
$-3g'$	+ ·10	− ·02	− ·01	+ ·00
$g-3g'$	+ ·06	− ·01	+ ·00	− ·01
$+2\varpi-2\varpi'$	− ·22	− ·01	− ·07	− ·04
g	− 2·50	− ·04	+ ·02	− ·05
$2g$	− ·18	− ·01	− ·01	− ·01
$-g-g'$	+ ·12	+ ·06	+ ·00	+ ·06
$-g'$	+ 2·40	+ ·12*	+ 15	+ ·10
$g-g'$	− 28·25	− ·31*	− ·34	− ·29
$2g-g'$	− 24·45	+ ·00	+ ·00	− ·03
$3g-g'$	− 2·95	+ ·02	+ ·03	+ ·02
$4g-g'$	− ·29	+ ·00	+ ·00	+ ·00
$-2g-2g'$	+ ·97	− ·02	− ·02	− ·02
$-g-2g'$	+ 13·22	− ·03	− ·02	− ·03
$-2g'$	+ 211·74	− ·03	− ·05	− ·07
$g-2g'$	+ 4586·66	− ·10*	+ ·02	− ·11
$2g-2g'$	+ 2369·74	+ ·01	+ ·39	+ ·16
$3g-2g'$	+ 191·96	− ·01	− ·01	− ·01
$4g-2g'$	+ 14·39	− ·01	− ·02	+ ·00
$5g-2g'$	+ 1·06	+ ·00	+ ·00	+ ·00
$-g-3g'$	+ ·49	− ·01	− ·04	− ·01
$-3g'$	+ 8·66	+ ·00	+ ·03	− ·01
$g-3g'$	+ 206·30	+ ·16*	+ ·19	+ ·18
$2g-3g'$	+ 165·54	+ ·02	+ ·01	+ ·01
$3g-3g'$	+ 14·61	− ·01	+ ·00	+ ·01

Argument.		Coefficient.	Correction to reduce to the valu… Hansen's Theory.	Hansen's Tables.
		"	"	"
$4g-3g'$	+	1·18	+·00	+·01
$-4g'$	+	·28	+·00	−·14
$g-4g'$	+	7·46	−·02	−·05
$2g-4g'$	+	8·12	+·01	+·00
$3g-4g'$	+	·74	+·02	+·02
$g-5g'$	+	·25	+·01	+·00
$2g-5g'$	+	·32	+·02	+·02
$g-3g'+4\omega-4\omega'$	+	·02	+·02	+·02
$2g-3g'$	−	·51	+·15*	+·14
$3g-3g'$	−	·69	+·05	+·05
$4g-3g'$	−	·29	+·00	+·00
$g-4g'$	+	1·15	+·03	+·02
$2g-4g'$	+	30·77	+·01	+·01
$3g-4g'$	+	38·45	−·02	−·02
$4g-4g'$	+	13·94	−·04	−·04
$5g-4g'$	+	1·95	+·03	+·03

nt.	Coefficient.		Correction to reduce to the values of Hansen's Theory.	Hansen's Tables.	Brown's Theory.
		″	″	″	″
2ω	+	·01	+·06	−·02	+·02
	+	·10	−·02	−·02	−·02
	−	·08	+·00	+·00	+·00
	−	·30	+·00	+·00	+·00
+ 2ω′	+	·37	+·03	−·03	+·00
	−	2·16	+·01	−·01	+·00
	+	·05	−·01	+·00	+·01
	+	·44	−·01	−·02	+·02
	+	6·37	−·01	+·05	+·01
	−	55·28	+·03	+·30	+·10
	−	·15	−·03	+·00	−·03
	+	·56	+·00	+·00	+·00
	−	·08	+·00	+·00	+·00
	+	1·50	+·05†	+·00	−·06
4ω − 2ω′	−	·53	−·01	+·00	−·01
	−	9·37	+·00	+·00	+·00
	−	5·74	+·00	−·01	+·00
	−	1·00	+·01	−·01	+·01
	−	·12	+·00	+·00	+·00
	−	·43	+·00	−·04	+·00
	−	·38	+·00	+·00	+·00
	−	·07	−·01	+·00	+·01
2ω − 4ω′	+	·25	−·03	−·01	+·00
	+	·00	+·00	+·02	+·03
	−	·04	−·01	+·02	+·01
5ω − 4ω′	−	·15	−·02	+·00	...
	−	·19	−·01	−·01	+·02
	−	·18	+·09†	+·09	−·02
ω	+	·08	+·00	+·00	+·00
ω	+	·42	+·00	+·00	+·00
	+	·09	+·00	+·00	+·00
ω − ω′	+	·35	+·03	+·02	+·00
ω − ω′	+	1·18	+·15†	+·41	+·08
	+	18·08	+·01	+·07	+·07
	+	1·25	+·02	+·03	+·03
	−	1·75	−·03	−·04	−·01
	−	18·73	+·03	−·42	+·04
	−	125·90	+·47†	−·54	+·15

Argument.		Coefficient.	Correction to reduce to the values of Hansen's Theory.	Hansen's Tables.	Brown's Theory.
		"	"	"	"
$2g - g'$	−	8·52	−·04	−·02	+·01
$3g - g'$	−	·59	+·00	+·00	−·01
$-2g'$	−	·15	−·02	+·00	−·01
$g - 2g'$	−	·59	−·01	+·00	−·03
$2g - 2g'$	−	·12	−·01	−·01	+·00
$g - 2g' + 3\omega - 3\omega'$	−	·03	−·01	−·01	−·01
$2g - 2g'$	+	·28	+·00	+·00	+·00
$3g - 2g'$	+	·15	+·00	+·00	+·00
$g - 3g'$	−	1·23	+·01	−·02	+·00
$2g - 3g'$	−	3·16	−·07*	−·06	−·07
$3g - 3g'$	+	·47	−·06*	−·06	−·07
$g - 4g'$	−	·08	+·00	−·01	+·00
$2g - 4g'$	−	·22	−·01	−·02	−·01
$3g - 4g'$	+	·08	+·02	−·01	−·01
$2g - g' + 3\omega - \omega'$	+	·02	+·00	+·00	+·00
$3g - g'$	+	·24	+·01	+·00	+·01
$4g - g'$	+	·04	+·00	+·00	+·01
$g - 3g' + \omega - 3\omega'$	−	·30	−·02	+·00	+·05
$g' + \omega + \omega'$	+	·06	+·02	+·05	−·02
$g + g'$	+	·58	−·03	−·02	+·00
g	+	·05	+·01	−·01	−·04

Differences of $\pm 0''{\cdot}01$ or even of $\pm 0''{\cdot}02$ mean little, as the greater part of their magnitude arises in the contraction from three to two places of decimals.

In seventeen cases where my own results differ sensibly from those found by Hansen from his last theoretical calculation, in eleven cases marked by an asterisk (*) Hansen's values are confirmed by Professor Brown, showing that in these instances my own approximations have not been carried sufficiently far or some combination of several terms has been overlooked; and in six cases marked with a dagger (†) my own results are confirmed by Professor Brown.

The details of the calculation of my own results are intended to form the third volume of the work on the lunar theory carried out at the Natal Observatory. The method adopted is that developed in the *Memoirs* of the Society for 1879, only substituting numerical values for the algebraical expansion of the different integrating factors. A good deal yet remains to be done to reduce the mass to a form available for printing, as nothing has been done for the last ten years when it was put away until funds were likely to be available for printing.

Distortion in Photographic Images with the 13-inch Astrographic Object-glass of the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The measures of the reference stars of the *Eros* photographs have incidentally provided material for a determination of the optical distortion of the object-glass. The reduction of the measures was made in the same way as those for the *Astrographic Catalogue* (Greenwich *Astrographic Catalogue*, vol. i., Introduction, p. xliv), three arbitrary constants being adopted for each plate, viz. two to fix the centre and one for the orientation—the correction for scale value being obtained from the mean of all the photographs, and the corrections for differential refraction and aberration being computed. The differences between the photographic and the assumed positions of the reference stars derived from meridian observations appear as residuals between the standard coordinates computed from the assumed right ascensions and declinations and those obtained from the measures. As the same star frequently occurs on a number of plates, and may be near the centre on some and at some distance from it on others, comparison of the residuals shown at different distances from the centre may be made to determine the distortion of the field, the images within 40′ of the centre being sensibly unaffected by distortion.

For example, the star B.D. + 44°, 326 occurs on photographs obtained on 1900 December 13, 15, and 16. The approximate coordinates and residuals on the several plates are given in the following table :

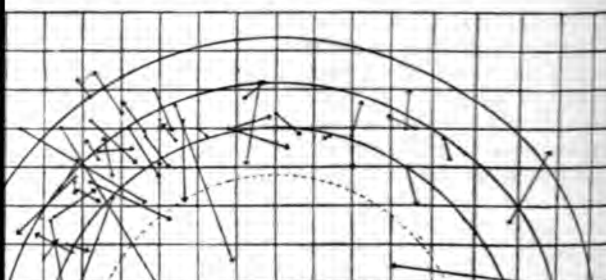
No. of Plate.	Position of Instrument.	Date.	Approximate Coordinates and Distance from Centre.			Residuals (Tab.−Obs.)	
			x.	y.	r.	Δx.	Δy.
		1900.	″	″	′	″	″
5288	E	Dec. 13	−1000	−3100	55	+·05	−·06
89	E		,,	,,	,,	−·06	−·22
90	E		,,	,,	,,	−·11	−·15
94	E		,,	,,	,,	+·13	−·34
97	E		,,	,,	,,	+·10	+·07
99	W	Dec. 15	−2400	− 200	40	+·16	−·40
5300	W		,,	,,	,,	−·15	−·36
04	E		,,	,,	,,	−·06	−·36
06	E		,,	,,	,,	+·02	−·27
07	E		,,	,,	,,	−·34	−·28
08	W	Dec. 16	−3000	+1300	55	−·13	−·42

Date.	Weight.	Mean Residuals. x.	y.
1900.		″	″
Dec. 13	5	+·02	−·14
,, 15	5	−·07	− 33
,, 16	1	− 13	−·42

ges within 40′ of the centre have been considered as fr
tical distortion, and the differences between the residu
en treated as entirely due to this cause. By subtracti
owing are obtained :

x.	y.	r.	Δx.	Δy.	No. of Plat
°		′	″	″	
000	−3100	55	−·09	−·19	5, 5
000	+1300	55	+·06	+·09	1, 5

quantities Δx and Δy were tabulated for all the referen
nd plotted as shown in the diagram, and the values
radial component) measured off.



· 45′ to 50′.

Δr.	No. of Photos.
5	3, 5
5	2, 6
1	5, 5
[illegible]	3, 5
5	1, 5
9	3, 3
3	7, 7
4	3, 2
7	1, 10
7	5, 5
3	7, 7
[illegible]	5, 7
[illegible]	5, 5
[illegible]	3, 6
5	1, 3
[illegible]	1, 1
[illegible]	5, 12
[illegible]	1, 4
2	5, 9
[illegible]	5, 3
[illegible]	2, 1
3	2, 6
[illegible]	7, 10
5	7, 8
[illegible]	7, 7
[illegible]	1, 7
3	3, 5
5	5, 3
[illegible]	2, 1
[illegible]	2, 1
[illegible]	3, 1
[illegible]	2, 1
[illegible]	3, 1
[illegible]	4, 4
[illegible]	4, 4
[illegible]	1, 4
[illegible]	1, 1
[illegible]	3, 4

r 50′ to 55′.

Δr.	No. of Photos.
+″·13	5, 1
+·18	3, 3
−·05	2, 1
−·11	5, 1
−·13	2, 3
−·19	1, 2
+·02	5, 5
+·02	5, 4
−·39	5, 6
+·33	1, 3
−·11	5, 3
−·28	3, 1
−·10	5, 3
−·04	6, 6
−·21	2, 3
+·19	3, 1
+·12	4, 1
−·05	6, 15
−·09	6, 3
−·04	2, 10
−·21	1, 1
+·04	2, 4
−·02	1, 6
+·49	1, 7
−·10	3, 1
+·22	4, 4
−·14	2, 3
−·18	3, 4
−·12	5, 1

r 55′ to 60′.

Δr.	No. of Photos.
−″·04	1, 2
+·20	5, 5
−·02	1, 5
−·13	1, 10
−·20	3, 6
−·22	6, 4
+·06	3, 11
+·19	4, 10
+·37	3, 4
+·07	1, 3
·00	3, 6
+·07	1, 3
+·12	6, 5
−·18	4, 13
·00	4, 8
+·03	6, 3
−·44	7, 4
+·13	2, 15
+·12	4, 1
+·02	3, 4
+·10	1, 2
+·02	1, 1
−·87	1, 6
−·39	4, 3
−·26	4, 3
−·11	4, 1
−·40	1, 3
−·12	3, 4
+·02	1, 1
−·30	3, 4
−·66	1, 3
−·56	1, 3

r 60′ to 65′.

Δr.	No. of Photos.
−″·47	1, 5
−·42	1, 1
+·26	1, 3
−·29	4, 2
−·30	5, 2
−·01	1, 2
−·43	2, 7
−·06	1, 4
+·28	3, 1
−·72	1, 3
−·15	1, 7
+·11	3, 4
−·15	1, 1
−·19	1, 1

r 65′ to 70′.

Δr.	No. of Photos.
−″·35	4, 13
−·20	1, 1
−·24	2, 4
−·41	3, 3
−1·02	2, 4
−·31	3, 3
+·24	1, 1
−·32	5, 1

r 70′ to 75′.

Δr.	No. of Photos.
+″·11	2, 5
−·74	7, 4
+·02	4, 1
−·12	2, 5

50–55	52·5
55–60	57·5
60–65	61·6
65–75	70·0

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three out of every four disturbances as falling between noon and midnight, and hardly one fourth between midnight and noon. Both agree also as to a fairly even distribution of the disturbances through these morning hours—0 hours to 11 hours inclusive. But there is a striking difference between the two catalogues as to the distribution during the evening hours, 12 hours to 23 hours. For whilst Table I. gives a very sharply defined maximum at 13 hours, Table IX. rises, with a regularity which precludes the possibility of accident, to a most unmistakable maximum at 18 hours.

It is not to be supposed that this difference indicates any change in the actual disturbances themselves taking place about the years 1881 or 1882; it is merely a question of a systematic difference in the taking out of the times of commencement.

Disturbances may be divided into two classes according to the character of their commencement. All very great storms and not a few minor ones begin with the characteristic sharp instantaneous impulse indicated by the letter "S" in Table I. These constitute the first class, and there is no ambiguity about the times of their commencement, except in the cases of a few long-continued storms, showing more than one of such sharp movements following a period of rest.

But there may be considerable ambiguity about the time of commencement of the second class, the more numerous but usually less intense disturbances where no such sharp initial movement is shown. These begin in many ways: sometimes by rapid but slight "fluctuations," sometimes by a single "wave," sometimes by a succession of small movements of varying character and amplitude.

Here there is room for some uncertainty in fixing the time of commencement. It is not an uncertainty which has any serious effect upon the *interval* between successive disturbances, nor in any case is it sufficiently large seriously to affect the relation of disturbances "in sequence."

TABLE XIV.

Hourly Distribution of Magnetic Disturbances.

Greenwich Civil Time.	1848 to 1881.	1882 to 1903.			1848 to 1903.		
		All.	Commencement.		Great.	Active.	Moderate.
h			Sharp.	Gradual.			
0	12	5	1	4	1	6	10
1	11	3	2	1	3	5	6
2	8	6	2	4	2	7	5
3	7	10	6	4	2	8	7
4	5	5	3	2	2	5	3
5	6	5	3	2	2	5	4
6	8	8	3	5	2	6	8
7	7	2	0	2	0	3	6

1848 to 1881.	1882 to 1903. All.	1882 to 1903. Commencement. Sharp.	1882 to 1903. Commencement. Gradual.	1848 to 1903. Great.	1848 to 1903. Active.	1848 to 1903. Moderate.
6	9	6	3	4	5	6
7	4	2	2	2	7	2
8	7	4	3	4	5	6
11	5	2	3	3	10	3
12	24	1	23	2	18	16
22	40	4	36	6	18	38
26	29	8	21	8	15	32
31	20	5	15	1	19	31
39	20	5	15	1	26	32
42	9	2	7	4	19	28
45	15	2	13	3	20	37
43	16	4	12	6	16	37
26	10	4	6	2	13	21
24	9	0	9	0	10	23

"great" disturbances are distributed throughout the 24 s with almost complete impartiality. So, too, are the dis- ınces which open with the characteristic sharp to-and-fro lse. But less than one in four of the "active," hardly one x of the "moderate," have their beginnings between mid- ; and noon ; and those of gradual commencement show the unequal tendency.

TABLE XV.

Hourly Distribution of Small Wave-movements, 1894–5.

Declination. Westerly.	Declination. Easterly.	Horizontal Force. Increase.	Horizontal Force. Decrease.	Greenwich Civil Time. h	Declination. Westerly.	Declination. Easterly.	Horizontal Force. Increase.	Horizontal Force. Decrease.
14	6	13	1	12	1	1	2	1
12	2	7	1	13		2	3	3
11	2	7	1	14		3	3	2
10	2	4	3	15		4	3	4
3		2	1	16	2	9	8	8
4		1		17		20	9	8
2		1	1	18		29	11	9
1			1	19		21	14	3
2				20		19	11	5
				21	2	16	16	4
				22	3	18	19	2
				23	4	8	8	

f our magnetic disturbances are excited from without, then ı any large number of them are taken it is natural to expect they will be found distributed indifferently tc the local time ıy one station. The "sharp" movements are, as far as we r, simultaneous over the whole earth, and hence are inde- ent of local time. So, too, with storms of the first rank : times of commencement are indifferent to local time. But hases of the after-development of a disturbance are not so pendent, and give clear indications of their connexion with resentation of the observing station with respect to the Sun; ı other words, with local time. With the less intense dis- ınces therefore, the phases connected with the local time of greater relative distinctness, and the times when the es of diurnal disturbance are most strongly marked are rally most often taken as the times of commencement. These s are : first, about six o'clock in the evening, when the rly "wave" in declination is most frequent ; and second, ly after noon, when a westerly movement made up of small ctuations" is apt to set in. In Table IX.—the catalogue of disturbances from 1848 to 1881—the former phase had the

most effect, for the times were determined by reference to the original photographic registers, and the sheets for the days preceding and following the disturbances were examined, and the most striking change was taken as the point of commencement. In Table I.—the catalogue of the disturbances from 1882 to 1903—the times were taken from the reproductions of the registers given in the plates of the Greenwich volumes, and these in the majority of cases began with Greenwich noon; hence the fluctuations of the early afternoon more frequently caught the attention. A reference to the original registers showed that, had the times for these later years been taken out from them, the same massing of disturbances around 18 hours civil time would have been seen in the catalogue of Table I. as in that of Table IX. For, though so many of our magnetic disturbances are world-wide, and though the sharp impulse with which not a few commence occurs, so far as we know, at the same minute of absolute time the whole world over, yet these disturbances often differ much at different stations in intensity, in character, and in the absolute times at which the subordinate phases develop. So far as Greenwich, at least, is concerned, there is a strong tendency for certain well-marked phases to recur with the same hours of local time as Tables XIV. and XV. indicate; the most obvious of these "local time movements" occurring between noon and midnight, and culminating near six o'clock in the evening.

It is obvious that stream-lines from the Sun, such as the interval-relation shows us to be the exciting instruments of our magnetic disturbances, must—since they overtake the Earth in its orbit—strike it first on the sunset arc and move across the sun-lit face to the sunrise arc. Over and above any *general* effect upon the Earth's magnetism as a whole, we may therefore naturally expect that disturbances thus excited will show certain *local* peculiarities dependent upon the presentation of the several observing stations towards the Sun at the moment when the solar stream overtakes the Earth. This presentation varies with the hours of the local day and with the season of the year, and therefore some kind of a diurnal inequality, some kind of an annual inequality, might naturally be expected in the disturbances recorded at any given station. Inequalities with daily and with annual periods do exist, not only in the diurnal range, but also in the disturbances. Table XIV., given above, illustrates the diurnal inequality in disturbances at Greenwich; Table XIX., which follows later, shows that there is an evident annual inequality. Whether these two inequalities here illustrated are those which should be looked for as a consequence of the action of the solar stream-lines is a point which I wish at present to reserve.

My present purpose is to call attention to two points: *first*, that local peculiarities, both diurnal and annual, are to be expected in the record of magnetic disturbances at any given station as a consequence of the solar excitation; and *second*, that

though the local peculiarities which have been observed with these daily and yearly periods tend to blur the evidence for the "Interval-Relation," they by no means efface it, for the whole of the evidence for that relation presented in my two former papers is evidence which is still outstanding after these and possibly other effects have done their utmost to impair or conceal it. I now offer a short catalogue of disturbances observed at a distance from Greenwich as an example of the manner in which the relation still comes out, even when no precise points of the disturbances are taken to work upon.

8. *Comparison of Greenwich and Toronto Records.*

Magnetic observatories seldom publish in their results any information about magnetic disturbances, or if they give such information it is usually not in a form convenient for comparing the observations made at different stations. But a short catalogue published in 1875 by the Director of the Toronto Observatory came under my notice, and seemed very suitable for my purpose. It is found on p. 55 of a volume of *Abstracts and Results of Magnetical and Meteorological Observations at the Magnetic Observatory, Toronto, Canada, from* 1841 *to* 1871 *inclusive*, and is headed "Dates (Astronomical Time) at which unusually large Disturbances of Declination occurred at the Ordinary Observation Hours, with the Amount of Abnormal Variation of each such Disturbance. Declination, Abnormal Variation not less than 15′. The + sign indicates an Easterly Disturbance, and — a Westerly Disturbance."

In Table XVII. the second and third columns are reproduced exactly from this catalogue; the third and fourth columns contain the number of the rotation and the longitude of the Sun's centre; the last four columns are derived from Table IX., and give the Greenwich disturbances for the same nine years. The first column gives a reference number for the Toronto disturbance. When two or more succeeding observations appeared to be made during the course of the same storm, a number is only given to the first, and the longitude of the Sun's centre is calculated for the time of that observation alone.

It will be observed that this is not a list of the times of the commencements of the disturbances, but of cases when, at the ordinary times of observation—2^h, 4^h, 10^h, 12^h, 18^h, and 20^h Toronto astronomical time—the declination magnet was found to be displaced from its normal position for the day and hour by more than 15′. A comparison shows that the times given fall on the average about nine hours later in absolute time than those given in Table IX., but a diurnal inequality is distinctly brought out, the numbers for the different hours running as under :—

TABLE XVI.

Toronto vil Time.	Disturbances of Declination.		
	Easterly.	Westerly.	Total.
h			
0	25	12	37
6	2	31	33
8	0	26	26
14	4	0	4
16	4	1	5
22	44	4	48
Total ...	... 79	74	153

le XVIII. shows that, though this diurnal inequality is brought out, and though the times given are not those of nmencements of the disturbances, nor of any specific und are, further, limited to six points of the day, yet that erval-Relation shows itself. It will be seen also from XVIII. that sometimes a sequence appears in the Toronto ue which would have been missed in the Greenwich list,

TABLE XVII.

rison of Magnetic Disturbances, 1863 *to* 1871, *as observed at Toronto and at Greenwich.*

Toronto. Date Toronto Mean Time			Toronto. Amount.	Toronto. No. of Rotation.	Toronto. Long. of Sun's Centre.	Greenwich. Ref. No. Table IX.	Greenwich. Date G.M.T.			Greenwich. No. of Rotation.	Greenwich. Long. of Sun's Centre.
							1863.	d	h		°
						196	Jan.	8	4	123	108·1
						197		10	10	...	78·5
863.	d	h	′		°						
an.	12	18	− 25·8	123	44·9	198		12	3	...	56·0
	24	12	+ 36·1	124	250·2	199		24	7	124	255·8
	25	20	− 24·3	...	..						
						200		29	4	...	191·6
						201		31	2	...	166·4
'eb.	6	20	− 20·7	...	74·6	202	Feb.	6	15	...	80·2
						203		22	8	125	233·4
	25	18	− 24·8	125	185·5	204		25	5	...	195·5
						205	Mar.	21	6	126	238·7
ıpr.	8	10	+ 16·5	127	356·2	206	Apr.	8	5	...	1·8
						207		15	6	127	268·9
fay	5	10	+ 27·1	128	359·5						
uly	6	10	+ 19·1	130	259·1						
	15	10	+ 27·4	...	140·0	208	July	15	9	130	143·5
						209	Aug.	13	10	131	119·4
						210		28	2	132	285·5
ept.	9	20	− 33·8	132	114·2	211	Sept.	9	6	...	124·8
	10	12	− 20·0	...	...						
						212		23	6	133	300·0
'ct.	8	10	+ 38·4	133	97·0	213	Oct.	7	8	...	114·2
'ov.	5	12	+ 15·9	134	86·6	214	Nov.	5	7	134	92·3
	14	10	+ 28·4	135	329·0	215		14	1	135	336·9
'ec.	11	20	− 18·6	...	327·7						
							1864.				
						216	Feb.	1	6	137	13·5
						217		11	8	138	240·7
						218	Mar.	6	6	139	285·7
						219		10	3	...	234·6
364.											
[ar.	31	12	+ 20·5	140	319·9						
						220	Apr.	27	6	141	319·6
pr.	29	10	+ 23·5	141	287·1						
[ay	5	12	+ 15·9	...	207·6	221	May	5	6	...	213·9
						222		25	6	142	309·3

Toronto.							Greenwich.					
Ref. No.	Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX.	Date. G.M.T.			No. of Rotation.	Long. of Sun's Centre.
	1864.	d	h	′		°		1864.	d	h		°
17	June	7	12	+ 34·2	142	131·1	223	June	7	4	...	138·4
18		8	18	− 23·6	...	114·5						
							224		22	16	143	293·2
19	July	19	10	− 35·9	144	296·3	225	July	18	15	144	309·7
							226	Aug.	13	7	145	330·1
20	Aug.	24	10	− 26·9	145	180·3						
							227	Sept.	16	19	146	234·5
							228		20	10	...	186·6
21	Sept.	23	4	+ 16·8	146	147·4	229		22	7	...	161·9
22	Oct.	12	20	− 22·1	147	247·9	230	Oct.	13	5	147	245·9
...		14	12	− 23·8	...	...						
...		14	20	− 15·6	...	...						
							231		19	3	...	167·9
							232	Nov.	11	2	148	225·1
23	Nov.	15	10	+ 23·8	148	165·1	233		15	1	...	173·0
24	Dec.	7	10	+ 16·1	149	235·2						
25		11	20	− 16·7	...	176·9	234	Dec.	12	2	149	176·6
							235		15	1	...	137·6
							236		23	3	...	31·1
								1865.				
							237	Jan.	11	5	150	139·8
							238		16	4	...	74·5
							239		25	2	151	317·1
							240	Feb.	15	6	...	38·4
							241		16	23	...	15·9
							242		21	2	152	321·6
							243	Mar.	15	7	...	29·0
	1865.											
26	Mar.	20	12	− 17·2	153	317·4	244		20	3	153	325·3
27	Apr.	15	10	+ 22·7	154	335·5	245	Apr.	16	6	154	327·4
							246	May	13	7	155	330·0
28	June	5	12	+ 17·9	155	20·0						
29		9	10	+ 24·6	156	328·2	247	June	9	11	156	330·6
30		15	10	− 21·5	...	248·8						
31	July	18	4	+ 15·9	157	175·3						
32	Aug.	2	2	+ 22·0	158	338·0	248	Aug.	2	6	158	338·7
...		2	18	+ 28·9	...	...						
...		2	20	− 63·4	...	...						

Toronto.				Greenwich.			
Date Toronto Mean Time.	Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX.	Date G.M.T.	No. of Rotation.	Long. of Sun's Centre.
1865. d h	′		°		1865. d h		°
Aug. 3 2	+ 33·2	...	...				
4 18	− 38·8	...	...				
				249	Aug. 10 6	...	232·9
11 18	− 21·5	...	210·2				
				250	14 7	...	179·5
Sept 20 12	− 16·2	159	35·1				
				251	Oct. 4 17	160	220·5
Oct. 12 20	− 17·5	160	110·4				
13 18	− 26·6	...	98·3				
13 20	− 31·9	...	...				
18 20	− 15·5	...	31·3	252	19 0	...	32·0
				253	26 3	161	298·0
30 18	− 22·2	161	234·1	254	29 23	...	247·5
30 20	− 22·0	...	...				
31 12	+ 15·4	...	...				
31 18	− 42·8	...	...				
31 20	− 20·5	...	...				
				255	Nov. 3 5	...	191·4
1866. Jan. 10 10	+ 20·4	163	9·7				
27 10	+ 15·9	164	145·9				
Feb. 7 10	+ 29·2	...	1·1	256	1866. Feb. 6 3	164	21·0
20 12	− 54·7	165	188·8	257	20 13	165	191·1
				258	23 6	...	155·5
Mar. 7 10	+ 15·4	166	352·3	259	Mar. 6 8	...	9·5
18 18	− 20·2	...	202·9	260	18 7	166	211·9
Apr. 3 18	− 15·0	167	351·9				
17 10	+ 17·4	...	171·5				
May 12 12	+ 17·4	168	200·0				
June 15 18	− 15·4	169	106·8				
Aug. 9 10	+ 15·5	171	103·5				
23 10	+ 15·5	172	278·4	261	Aug. 23 4	172	284·6
29 18	− 20·2	...	194·7				
				262	Sept. 9 5	...	59·5
Sept. 17 18	− 27·5	173	303·8				
Oct. 3 10	+ 25·7	...	97·1	263	Oct. 4 4	173	90·1
5 18	− 15·9	...	66·3	264	6 3	...	64·3

Toronto.						Greenwich.					
Date Toronto Mean Time.		Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX.	Date G.M.T.			No. of Rotation.	Long. of Sun's Centre.
1866.	d h	′		°		1866.	d	h		°
Oct.	7 18	− 18·9	...	39·9						
	9 12	+ 22·7	...	16·8						
	10 18	− 33·6	...	0·3						
	11 18	− 20·2	174	347·1	265	Oct.	12	6	174	343·5
	13 10	+ 29·3	...	325·1						
	18 10	+ 27·0	...	259·2						
	30 12	+ 16·2	...	99·8						
Nov.	1 10	+ 37·4	...	74·6						
	25 20	− 18·2	175	112·7	266	Nov.	26	3	175	111·7
					267	1867. Feb.	8	6	178	215·5
					268		13	6	...	149·6
					269	Mar.	6	5	179	233·5
					270		10	6	...	180·3
1867.					271	May	28	7	182	216·4

[redacted]

Toronto. Ref. No.	Date Toronto Mean Time.	Amount.	No. of Rotation.	Long. of Sun's Centre.	Greenwich. Ref. No. Table IX.	Date G.M.T.	No. of Rotation.	Long. of Sun's Centre.
	1866. d h	′		°		1868. d h		°
					285	July 14 13	...	160·3
78	Aug. 4 10	+ 20·4	198	241·2				
					286	Aug. 30 6	199	262·7
79	Sept. 15 12	− 20·9	199	45·2	287	Sept. 15 13	...	47·6
...	15 18	− 41·7	...	...				
...	15 20	− 17·7	...	...				
80	26 10	+ 44·4	200	261·1	288	27 5	200	253·6
...	26 12	+ 21·9	...	...				
81	30 12	− 69·9	...	207·2	289	30 6	...	213·5
...	30 18	− 28·2	...	...				
					290	Oct. 19 4	201	323·9
82	Oct. 22 12	+ 42·8	201	277·0	291	22 3	...	284·9
...	22 18	− 40·1*	...	...				
83	23 18	− 33·2	...	260·5	292	24 3	...	258·5
...	25 18	− 18·8	...	...				
...	25 20	− 16·8	...	...				
84	Nov. 19 10	+ 24·4	202	268·9	293	Nov. 19 4	202	275·1
85	1869. Jan. 19 20	− 15·2	204	179·9	294	1869. Jan. 20 12	204	174·0
86	Feb. 3 10	+ 20·7	205	346·9	295	Feb. 2 11	...	3·4
87	23 10	+ 33·0	...	84·5				
					296	Mar. 9 7	206	264·6
					297	18 1	..	149·3
					298	Apr. 2 5	207	309·3
88	Apr. 5 12	− 22·8	207	262·9				
...	6 4	+ 21·8	...	...				
					299	8 5	...	230·1
89	15 2	+ 20·1	...	136·4	300	14 23	...	141·0
90	May 7 10	+ 18·8	208	201·4				
...	8 12	+ 16·3	...	...				
91	13 2	+ 31·3	...	126·4	301	May 13 2	208	129·3
...	13 4	+ 24·1	...	...				
					302	30 18	209	255·6
					303	June 6 14	...	165·2
92	June 15 18	− 16·3	209	41·0				
93	24 4	− 23·6	210	289·7				
					304	29 7	210	224·6
					305	July 3 10	...	169·9
					306	18 9	211	332·1

97 Sept. 27 18

98 Dec. 13 20

1870.
99 Jan. 8 10
100 26 12

101 Feb. 1 12

102 Mar. 30 10
103 Apr. 4 18

104 June 14 10 +

Toronto.							Greenwich.					
Ref. No.	Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX	Date G.M.T.			No. of Rotation.	Long. of Sun's Centre.
	1870.	d	h	′		°		1870.	d	h		°
108	Oct.	23	18	+ 15·5	228	345·4	338	Oct.	23	22	228	346·1
...		24	12	− 22·8	...	...						
...		24	20	− 21·6	...	...						
109	Nov.	8	10	+ 23·0	...	138·8	339	Nov.	7	19	...	150·0
...		8	18	− 16·2	...							
110		18	20	− 22·7	...	1·5	340		19	3	...	0·7
111	Dec.	15	20	− 17·5	229	5·7	341	Dec.	15	16	229	10·8
...		16	20	− 17·6	...	...						
							342	1871. Jan.	4	5	230	113·4
							343		12	22	231	358·7
112	1871. Feb.	11	12	+ 16·7	232	326·3	344	Feb.	10	11	232	342·9
							345		26	4	...	136·1
							346	Mar.	1	6	...	95·4
							347		22	8	233	177·6
113	Mar.	26	20	− 15·7	233	115·3	348		27	2	...	115·0
							349	Apr.	1	8	...	45·7
114	Apr.	4	10	+ 16·9	...	2·1						
							350		9	5	234	301·8
							351		13	9	...	246·8
115		17	10	− 15·5	234	190·5	352		17	7	...	195·1
116		23	18	− 24·9	...	106·8						
117		27	20	− 20·2	...	52·9	353		28	1	...	53·0
...		28	20	− 18·5	...	...						
118	May	24	12	+ 15·8	235	60·3						
119		26	10	+ 19·0	...	34·9						
120	June	17	12	− 16·7	236	102·7	354	June	17	12	236	105·6
121	July	3	12	+ 15·0	237	250·8						
122		21	12	+ 15·7	...	12·7	355	July	21	13	237	15·0
							356	Aug.	6	1	238	170·0
123	Aug.	12	10	+ 23·1	238	82·8						
							357		21	9	239	327·3
							358		24	8	...	288·2
							359	Sept.	7	8	...	103·3
							360	Oct.	14	5	241	336·6
							361	Nov.	1	6	...	98·7
							362		9	7	242	352·7
							363		19	19	...	214·2

..	134	
12	135	[illegible]
13*	136	[illegible]
23	148	1
25	149	1
26	153	3
27	154	3
...	155	
29	156	3
...	157	
32	158	3
34*	159	3
37	160	3

9. *The Ann*

I am indebte
disturbances whic
complete magneti
which every day
"moderate," or "
has used the first
appearing in the
I may perhaps be
fifty-five years in
sums of the numb

gures bear out Mr. Ellis's statement that "the spring maxi- appears on the whole to fall somewhat before the equinox, ;he autumn maximum somewhat after the equinox." It also ırs that the summer minimum in like manner falls before ıolstice, and the winter minimum decidedly after. The ıer minimum is very sharply marked, and coincides with ›eriod when the Sun's equator is on the centre of the disc, ;he direction of rotation makes the greatest angle with the tic. The table as a whole suggests that this strongly marked al inequality is not due to a single cause alone, but to a ›ination of two or more, inasmuch as the curve is not ıetrical about either the equinoxes or the dates when the ; equator is on the centre of the disc. It will be necessary btain similar figures from observatories having seasons 'ing markedly from those at Greenwich, and especially from 'vatories in the southern hemisphere, before a satisfactory pretation can be placed upon the peculiarities shown by this al inequality.

TABLE XIX.

Annual Distribution of Magnetic Disturbances.

ı.	To.	Great.	Active.	Moderate.	Total.	
30	Jan. 13	0	8	124	132	
14	„ 28	0	19	178	197	
29	Feb. 12	5	11	194	210	
13	„ 27	8	30	197	235	
28	Mar. 14	3	14	191	208	Hel. lat. of Earth $-7^{\circ}\cdot2$
15	„ 29	3	15	199	217	Spring equinox
30	Apr. 13	3	18	197	218	
14	„ 28	4	18	149	171	
29	May 13	2	8	162	170	
15	„ 29	2	8	125	135	
30	June 13	0	9	99	108	Hel. lat. of Earth 0°
14	„ 28	1	8	113	122	Summer solstice
30	July 14	4	13	129	146	
15	„ 29	2	7	135	144	
31	Aug. 14	8	17	133	158	
16	„ 30	3	5	142	150	
31	Sept. 14	7	16	181	204	Hel. lat. of Earth $+7^{\circ}\cdot$
16	„ 30	3	10	195	208	Autumn equinox
1	Oct. 15	5	18	181	204	
16	„ 30	4	17	199	220	
31	Nov. 14	3	15	165	183	
15	„ 29	5	9	156	170	
30	Dec. 14	1	7	145	153	Hel. lat. of Earth 0°
15	„ 29	1	7	141	149	Winter solstice

Determination of Longitude on the Planet Jupiter.
By G. W. Hough.

In the *Monthly Notices*, vol. lxiv. pp. 824–834, I published an article on longitude determinations on the planet *Jupiter*.

It would appear from a paper by Mr. A. S. Williams in *Monthly Notices*, vol. lxv. pp. 167–181, on the same subject that I failed to make clear some points in the discussion. Some further explanation may, therefore, be desirable.

The eye-estimate method has been used by many distinguished astronomers in the past in determining the rotation period of *Jupiter* and *Saturn*, and in common with everybody I imagined that it was a fairly reliable method. I had very little faith in Schmidt's variable error, and also supposed there was a *real* personal equation between different observers. The comparison of eye-estimates with the micrometer measures, however, has shown such grave errors that astronomers ought clearly to understand that a precision observation cannot be made by this method.

In meridian observations the transit of a star is observed over a group of fixed wires, from five to fifteen in number. Suppose all the wires were removed and the transit observed over an imaginary wire bisecting the field, the latter being analogous to that employed in eye-estimates. How would the two methods compare in point of accuracy in right ascension work?

The observations of the Barnard White Spot on *Saturn* in 1903, the only conspicuous spot on the disc, showed that experienced observers differed nearly twenty minutes on the same night, not once, but repeatedly. I think astronomers would not regard such as precision observations. I have already shown that a micrometer used for a fraction of the time required to secure such crude estimates would furnish observations of precision such as are demanded in other directions. If, therefore, anything I can say will induce observers who have micrometers to use them when we discover another suitable spot for determining the rotation of *Saturn* my time will not be entirely wasted.

In my previous paper I compared the micrometer results with a previously computed ephemeris by Marth to show that there was no variable or cumulative error.

As all the conclusions arrived at are based on the assumption that micrometer work is subject to accidental error only, some further explanation on this point may be desirable.

In the determination of longitude the central meridian of the disc is not directly used. The measures are referred to the limbs of the planet, and every measure for longitude is virtually a measure of the equatorial diameter, the spot or marking serving

as an intermediate step. In fact, the constants for the size of the disc were determined from such observations.

As the size of the disc from these differential measures is in harmony with direct measures it is obvious that there was no variable or cumulative error. When objects are observed at a considerable distance from the central meridian the accidental error, or the time of passage over the central meridian, may be materially increased owing to errors in the adopted constants for reduction—viz. the size of the disc, latitude, and length of the object.

If measures were always made near the central meridian I have good grounds for thinking that the mean accidental error would conform to theory—viz. one minute of rotation time.

In order to ascertain the mean personal equation and variable error all the observations used in the discussion were compared with an ephemeris derived from the micrometer measures.

For convenience in some cases the Marth-Crommelin ephemeris was corrected to conform to the true rotation-period; then both the micrometer and eye-estimates were compared, as in the example given for 1887. The residual errors, therefore, in all cases depend on the rotation-period derived from the micrometer measures.

In the eye-estimate method it seems to me there are two sources of error of vital importance.

First, personal equation.

Second, variable error, first pointed out by Schmidt.

Personal Equation.

What does personal equation indicate in eye-estimate observations? If the personal equation amounts to six minutes it means that the observer divided the disc into two *unequal parts*; that his central meridian, which he thought bisected the disc, was 1″ on one side, or one-fortieth of the diameter of the disc in error.

The range in the mean personal equation for different years (*Monthly Notices*, vol. lxiv. p. 831) is about eight minutes, which means that whenever the personal equation is changed a new central meridian is chosen. Schmidt found, from eye-estimates alone, a range of nine minutes in the personal equation for different observers. Now if the personal equation varies over such wide limits for the same observer, or for different observers, it means that the disc is not bisected by this method, and precision observations are not made. Hence, also, we may conclude that the range in personal equation is a correct measure of the amount of error in eye-estimates. It has also been shown that the personal equation is not the same for different spots observed on the same night, nor for the same spot at different oppositions.

Variable Personal Equation.

But the most serious error is the "variable personal equation," which is introduced when observations extend over a considerable interval of time. I think the term "variable personal equation" has been misunderstood; the designation "cumulative error" is preferable.

During an opposition spots or markings may be observed for 200 days or more. If, then, at the beginning of the series the micrometer and the eye-estimate are in agreement, and at the end of the series there is a difference of ten minutes more or less, and this difference varied substantially with the time, such difference has been designated as "variable personal equation" or cumulative error. It is not to be confounded with accidental error or constant error. In all the sets of observations which I compared with the micrometer, in which this error was apparent, with one exception, the difference between the micrometer and the observer increased or decreased with the time.

Variable personal equation, then, means that the observations are not referred to the same central meridian, but are gradually shifted to one side.

In this discussion nineteen sets of observations, made by five different persons, were compared with the micrometer, and in fifteen sets the cumulative error was well defined. That it may clearly be seen what effect "variable personal equation" has on the rotation period, I have determined it for the values given in *Monthly Notices*, vol. lxiv. p. 829.

			Time interval in Days.	Variable personal equation. min.	Error on rotation-period. sec.
Barnard	1891	Red Spot	122	5	1·0
,,		Long Red	85	0	0·0
,,		Small Black (a)	92	15	4·0
,,		,, (b)	85	7	2·1
Gledhill	1898	Black	144	10	1·7
Williams	1900	Red Spot	113	6	1·3

For the above six sets of observations only one, Barnard, Long Red, was free from "variable personal equation," and hence gave the correct rotation-period.

The "variable personal equation" or cumulative error may be shown to exist independently of the micrometer observations by simply comparing the rotation periods given by different observers for the same spot at the same opposition.

Schmidt's observations on the Red Spot (*Ast. Nach.* 2410) have been repeatedly quoted as a specimen of good eye-estimate work. The comparison with the micrometer measures may be of interest.

I have reduced the observations made between 1880 August 3

and 1881 March 20, a time interval of 229 days, with a variable increasing rotation-period, and compared them with the micrometer observations covering the same interval, with the following results :—

Mean personal equation	$-3^{\cdot}04$ min. (99 obs.)
Variable personal equation ...	3
Mean O—E	$\pm 2^{\cdot}65$
Mean actual error	$\pm 4^{\cdot}05$

Schmidt found for a uniform rotation period O—E $\pm 3^{m}\cdot 0$.

The four observations made in 1879 were not used, but were reduced separately. When these are included the variable personal equation is about 6 min.

Motion in Longitude.

The observations of the past twenty-five years have shown that the motion of the spots and markings seen on the planet *Jupiter* is smooth, never abrupt, as has been imagined by some observers. The rotation-period may be regarded as constant for a short time interval, sometimes for the whole opposition ; but in some cases the variation is so great that the observations can only be satisfied by assuming a uniformly decreasing or increasing period.

If observations could be made with greater precision I imagine a variable rotation-period would be apparent in all cases. As the labour required to compute an ephemeris for a variable period is considerable, it is only used when the observations made during an opposition cannot be fairly satisfied with a uniform period. At mean distance 1″ represents 2300 miles, and hence a spot 1″ in diameter represents about 4,000,000 square miles.

The objects that are observed are usually many millions of miles in area, and presumably have mass. We should not expect any abrupt change in direction or rate of motion in a moving mass.

My observations of a White Spot made in 1881 have been quoted a number of times in proof of the abrupt displacement of a spot on the disc of the planet. I find three observations, October 8, 18, 20, and again three others, November 21, 24, 30, which show abnormal residuals (O—E) about 10 min. greater than the mean of the residuals for the whole opposition of 252 days. As such irregularities are not found in any other set of measures, we should not be warranted for an isolated case in assuming irregular motion, even if there was no way to account for it. But the explanation is simple. This spot, which was observed for a number of years, appeared for a short time in 1881 as a long rift in the equatorial belt, its general appearance being an oblong spot. The apparent displacement was simply

the use of a different reference point in making the
es. When the spot appeared as a long rift the preceding
s used, otherwise the middle of the spot.
en the rotation-period changes a number of seconds
an opposition one might naturally infer irregular motion
bservations are compared with an ephemeris based on a
period.
ny cases of alleged irregular motion may possibly be ex-
on this hypothesis.
example of irregular motion may be found in *Ast. Nach.*

pot observed for 205 days showed residuals $+12^m$ at the
ng and end of the series, and -3^m near the middle.
however, the observations were compared with an
ris based on a uniformly increasing period they were well
l, and gave a mean residual $(O-E)+2^m{\cdot}0$.
sequent to 1879, the observations of the Red Spot covering
uccessive oppositions were fairly represented by assuming
rmly increasing rotation-period. An examination of the
ls, however, indicated that the initial rotation-period was
ite correct, or that a third term was required fully to
the observations.
general, whenever there is a marked difference in the

this error will be apparent by reference to the table of longitude given by Mr. Williams in *Monthly Notices* (Red Spot, 1887), vol. lxv. p. 175. At this time the rotation-period was practically stationary, and a constant longitude was maintained when the observations were referred to Marth's ephemeris.

Schmidt thought the variable error depended on the hour-angle, which *indirectly* depends on the time.

How does this peculiar error originate? A possible explanation is that in some way subsequent observations are influenced by preceding ones. When the rotation-period conforms very closely to a previously prepared ephemeris, as has been the case for the Red Spot, the presupposed time has a very important bearing on the observations made.

For some years the Red Spot was for a large portion of the time invisible, and its position could only be determined by the hollow in the belt; an object not well adapted for an observation of precision. We find, however, eye-estimates giving an average mean residual $O - E = \pm 1{\cdot}0^{m} = 0''{\cdot}2$. Such a degree of precision is seldom reached with the micrometer in the observation of well-defined spots, and is far beyond anything possible for the micrometer in the observation of the hollow.

The eye-estimate method for ascertaining the rotation time of a planet is simple and direct, and will continue to furnish observations of value. When the time interval is long, viz. between two oppositions, the errors I have investigated, accidental, personal equation, and cumulative, will have but little effect on the mean rotation-period derived.

It would be a curious anomaly, however, in astronomical development if there could be no improvement on a method devised more than two centuries ago, when modern instruments of precision were unknown.

Not very long ago, before equatorial mountings and driving clocks were in common use, the ring micrometer was pretty generally used for fixing the place of a comet. At the present day, however, I think few astronomers would make use of it except as a last resort.

The modern micrometer enables the observer to measure by repetition spaces smaller than can be seen with the telescope.

The principles involved in measurement are the same, whether the instrument is used for ascertaining the distance of two stars, or the distance of markings on a planetary disc. It strikes me, therefore, as a self-evident proposition that one could bisect a planetary disc with greater precision by the help of a micrometer than without one.

The Equatorial and Polar Diameters of Jupiter as measured with the Greenwich Transit-Circle, 1880–1901. By A. M. W. Downing, D.Sc., F.R.S.

In meridian transit observations the diameter of a planet may be defined as the perpendicular distance between the verticals which are tangents to the first and second limbs of the planet. This may be called the horizontal diameter at meridian passage. In the same way the vertical diameter at meridian passage is the perpendicular distance between the horizontal tangents to the north and south limbs. In the case of *Jupiter* the horizontal and vertical diameters are not generally the same respectively as the equatorial and polar diameters owing to the inclination of the planet's axis to the circle of declination.

Let $\quad P =$ the position-angle of the planet's axis

$$c = \sqrt{1-e^2} = \frac{b}{a} = \frac{\text{polar diameter}}{\text{equatorial diameter}}$$

$$\cot P' = \frac{\cot P}{c}, \text{ and } \tan P'' = \frac{\tan P}{c}$$

then, with sufficient accuracy in the case of *Jupiter*,

$$\text{hor. diam.} = \text{equat. diam.} \times \frac{\cos P}{\cos P'}$$

and

$$\text{vert. diam.} = \text{polar diam.} \times \frac{\cos P}{\cos P''}$$

Also let the true diameter = tabular diam. $(1+y)$, and let z be the correction to the adopted value of $\frac{b}{a}$ or c; then the equations of condition furnished by the meridian observations of diameters are:

(1) From the transit observations

$$\text{equat. diam.} \times \frac{\cos P}{\cos P'} \times y + \text{equat. diam.} \times \sin P \,.\, \sin P' \times z$$
$$= \text{observed correction to tabular horizontal diameter.}$$

(2) From the Z.D. observations

$$\text{polar diam.} \times \frac{\cos P}{\cos P''} \times y - \text{polar diam.} \times \sin P \,.\, \sin P'' \times z$$
$$= \text{observed correction to tabular vertical diameter.}$$

The variation of its coefficient is not sufficiently great to enable us to determine z satisfactorily in this way, and it seems better to adopt the value of c corresponding to the compression

of the disc of *Jupiter* deduced from the motion of the apsides of the orbit of the fifth satellite, viz. $c = {\cdot}9355$, and put $z = 0$ in the equations of condition. The observations discussed in this paper have accordingly been reduced with this value of c. The adopted value of the equatorial diameter is $37''{\cdot}765$ at distance $5{\cdot}2$. The corresponding value of the polar diameter is $35''{\cdot}330$. The observations included in the following table are taken from the *Greenwich Observations* for the different years, and are restricted to observations made between 15 hours and 9 hours of mean time, so as to be representative of each opposition, and free from complications arising from phase, difference of brightness of background of sky, &c. The subscript figures in the fifth and sixth columns indicate the number of observations included in each mean result.

It will be noted that the observations of horizontal and vertical diameters are quite independent of each other, and are made by quite different methods; also that the former alone are used to determine the equatorial, and the latter alone the polar diameter.

Mean Date.	Position-angle of Axis.	Tabular Diameters.		Observed Corrections to Diameters.	
		Horizontal.	Vertical.	Horizontal.	Vertical.
	°	"	"	"	"
1880 Oct. 9	336	49·17	47·06	$+1{\cdot}90_{24}$	$+2{\cdot}21_{23}$
1881 Nov. 11	345	48·77	46·07	$+1{\cdot}27_{28}$	$+2{\cdot}15_{28}$
1882 Dec. 19	359	47·49	44·42	$+1{\cdot}52_{20}$	$+2{\cdot}33_{19}$
1884 Feb. 8	13	45·07	42·44	$+1{\cdot}12_{19}$	$+1{\cdot}89_{20}$
1885 Mar. 7	23	43·84	41·83	$+1{\cdot}72_{28}$	$+2{\cdot}29_{28}$
1886 Apr. 4	25	43·32	41·54	$+1{\cdot}71_{24}$	$+2{\cdot}21_{24}$
1887 Apr. 27	22	43·84	41·78	$+1{\cdot}56_{24}$	$+1{\cdot}89_{24}$
1888 May 23	12	45·03	42·37	$+0{\cdot}82_{27}$	$+1{\cdot}98_{26}$
1889 July 3	358	46·51	43·51	$+0{\cdot}69_{22}$	$+2{\cdot}31_{22}$
1890 Aug. 9	344	47·84	45·23	$+1{\cdot}51_{26}$	$+2{\cdot}23_{26}$
1891 Sept. 30	336	47·83	45·78	$+1{\cdot}41_{10}$	$+1{\cdot}97_{9}$
1892 Oct. 14	336	49·16	46·99	$+0{\cdot}72_{24}$	$+1{\cdot}99_{24}$
1893 Nov. 27	346	48·40	45·65	$+0{\cdot}39_{27}$	$+1{\cdot}73_{27}$
1894 Dec. 31	1	47·06	44·03	$+0{\cdot}70_{29}$	$+1{\cdot}72_{29}$
1896 Feb. 13	15	44·79	42·25	$+0{\cdot}08_{15}$	$+1{\cdot}02_{15}$
1897 Mar. 12	23	43·65	41·71	$+0{\cdot}51_{21}$	$+1{\cdot}77_{21}$
1898 Apr. 8	25	43·33	41·53	$+0{\cdot}21_{27}$	$+1{\cdot}60_{27}$
1899 May 5	21	43·90	41·76	$+0{\cdot}88_{25}$	$+1{\cdot}36_{26}$
1900 May 30	10	45·25	42·51	$-0{\cdot}19_{22}$	$+1{\cdot}14_{23}$
1901 July 13	356	46·62	43·63	$+0{\cdot}38_{31}$	$+1{\cdot}40_{31}$

Combining the observations of horizontal diameter and giving equal weights to the mean results obtained for each opposition, we have

$$y = +{\cdot}0205 \pm {\cdot}0020$$

Hence the correction to the adopted value of the equatorial diameter at distance 5·2 is

$$+''{\cdot}774 \pm ''{\cdot}075$$

and the resulting value of the equatorial diameter is 38″·54.

Treating the observations of vertical diameter in the same way, we find

$$y = +{\cdot}0426 \pm {\cdot}0013$$

The correction to the adopted value of the polar diameter at distance 5·2 is

$$+1''{\cdot}505 \pm ''{\cdot}046$$

and the resulting value of the polar diameter is 36″·84.

An inspection of columns 5 and 6 of the table, however, shows that there is an apparent progressive change in the values of the observed horizontal and vertical diameters, probably due to changes in the staff of observers during the interval covered by the observations here discussed, with corresponding changes in the mean personal equation as applying to these observations.

Perhaps the most conspicuous change occurs in 1892–3; and on this account it has been considered advisable to divide the series of observations into two parts, the first extending from 1880 to 1892, and the second extending from 1893 to 1901.

Treating these partial results exactly as before, we find from the observations of horizontal diameter, 1880–1892, that the correction to the adopted value of the equatorial diameter is

$$+1''{\cdot}080 \pm ''{\cdot}067$$

and from the observations of horizontal diameter, 1893–1901, that the correction is

$$+''{\cdot}308 \pm ''{\cdot}068$$

The values of the equatorial diameter from these two series of observations are therefore

from 1880–1892	... ...	38″·84
1893–1901	... ...	38·07

Similarly the observations of vertical diameter give the corrections to the adopted value of the polar diameter

from 1880–1892	... ...	$+1''{\cdot}700 \pm ''{\cdot}029$
1893–1901	... ...	$+1{\cdot}209 \pm {\cdot}054$

with the corresponding values of polar diameter

from 1880–1892	37″·03
1893–1901	36·54

The results of this discussion exhibited in a tabular form are as follows :

Included Oppositions.	Equatorial Diameter.	Polar Diameter.
1880–1892	38″·84	37″·03
1893–1901	38·07	36·54
1880–1901	38·54	36·84

Report on Observations of Jupiter for 1903–4.
By Major P. B. Molesworth, R.E.

Part I. Preliminary.

Place.—Trincomali, Ceylon. Longitude east, $5^h\ 24^m\ 55^s{\cdot}6$; latitude north, $8°\ 33'\ 24''{\cdot}2$. Observatory ninety-one feet above mean sea level.

Telescope.—Calver silver on glass Newtonian ; 12¼-inch aperture ; ninety-two inches focus, equatorially mounted with driving clock. The eyepieces generally employed were a Huyghenian of 230 and a Steinheil monocentric of 270.

Nomenclature.—The nomenclature I have adopted has been in use here for several years, but differs slightly from the one generally used. A diagram is given on p. 700, showing the identification of each portion of the planet. In addition to the name, a letter is allotted to each zone and belt for identification, and these are qualified by the symbols N = North, S = South, C = centre.

Scope of the Observations.—These were begun on 1903 April 21, and continued before dawn till 1903 July 30. They were continued in the evening from 1903 August 18 to 1904 February 23. They thus cover an inclusive period of 310 days, on ninety-five of which I was absent from Trincomali ; so that 215 nights were available. One hundred and forty-one of these (65·6 per cent.) were utilised, and the planet observed for central meridian transits for a total period of 287 hours ; an average of two hours four minutes per working night. Five thousand six hundred and fifty-one C.M. transits were taken, an average of nearly twenty an hour. Eight sets of measures were also made for latitude.

Colour estimations of the different belts were made on ninety-six nights. Satellite phenomena were observed on sixty-

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(*C*) *S. Temp*

(*D*) *S. Tropical Belt.*—The darkest and most distinct of the ıinor belts; decided slate grey with sometimes a faint tinge of lue. It contains some very dark streaks, generally broad and notted, and sometimes double, but more rarely double this year han usual. The average period ($9^h\ 55^m\ 18^s{\cdot}45$) is much the ame as that of the S. Temperate Zone. It varies little from ear to year and may be taken as reliable.

The Red Spot.—Practically unchanged in recent years. The readth of the bay remaining fairly constant throughout the bservations. The S. Equatorial Belt remains widely double nd rather faint for some distance preceding the bay. The preeding shoulder is generally very faint and slightly rounded, the ollowing shoulder very dark and pointed. A curved wisp is enerally seen to join the latter with the S. Tropical Belt a short listance preceding it. On rare occasions a very faint similar risp has been noted from the preceding shoulder, completing the val of the Red Spot Bay. The bay is shallow but symmetrical. The Red Spot is very faint, like a faint grey stain with a slight inge of brown under the best conditions, when the whole outline an just be made out. The ringed appearance is not so prominent s in recent years. Once or twice a very faint diffuse horizontal treak was seen crossing the spot in a line between the shoulders, ut not extending the full width of the bay. The following end f the spot is slightly darker than the rest. The period for the irst part of the apparition was rather more rapid than usual $9^h\ 55^m\ 39^s{\cdot}55$), but about 1903 August 18 it slowed down to $^h\ 55^m\ 42^s{\cdot}30$. The mean period was $9^h\ 55^m\ 41^s{\cdot}19$.

Great S. Tropical Dark Area.—One of the most striking eatures of the apparition, preceded and followed by two very rilliant white spots. The motion of the centre of the area was airly uniform with a mean period of $9^h\ 55^m\ 21^s{\cdot}83$, but the ngth of the shade increased from about 29° of longitude on 903 April 25 to nearly 50° on 1903 July 29. After this it emained fairly constant till near the end of the observations, hen it again appeared to increase. The first increase of length eems to have been due to a retardation of the following end, hile the second was due to an acceleration of the preceding nd. Under good definition it presented a very curious appearnce, being made up of numerous smoky wisps, springing from nots in the S. edge of S. Equatorial Belt. There were several arker condensations in it, and a dull white patch near its entre. The average period of the preceding end was $9^h\ 55^m\ 19^s{\cdot}43$, nd of the following end $9^h\ 55^m\ 24^s{\cdot}23$, giving an average period or the centre of $9^h\ 55^m\ 21^s{\cdot}83$. It was nearing conjunction with he Red Spot when the observations ended.

(*E*) *Other Spots in S. Tropical Zone and S. Edge of S. Equarial Belt* (Fs).—The S. Tropical Zone was generally bright ilky white, not much inferior to the Equatorial Zone. It is rossed by several faint wisps. The spots in this zone appear to

have been considerably retarded in period compared with previous years. The average being $9^h\ 55^m\ 48^s{\cdot}47$.

(*F*) *S. Equatorial Belt.*—Much the most prominent of the belts, dark and distinct throughout, but showing a decided change of tint. Early in the observations it was a warm bluish purple; warmest just following the Red Spot Bay, and bluest in the darker parts of the N. edge. This gradually changed to a brownish purple in August, the brown tint growing more decided as time went on. The *S. edge* was very dark and clean-cut, showing the same slight tendency to the formation of shallow white bays that I have noticed in previous years. The centre of the belt was nearly always rifted, the rift (especially in June) having sometimes a decided yellow tinge. The period of the white spots in it was found to be $9^h\ 51^m\ 27^s{\cdot}19$ this year, showing a progressive acceleration in period of about five seconds per annum when compared with the results for 1901 and 1902-3.

The *N. edge* is more regular than the S. edge, and is much knotted and disturbed. The motion of the dark projecting knots is not uniform, and both these and the white spots in S. edge of Equatorial Zone sharing their motion are very hard to follow, correct identification being very difficult. The deduced average period ($9^h\ 50^m\ 22^s{\cdot}72$) agrees well with my results for previous years, though these differ somewhat from those obtained by Denning and Phillips.

(*GK*) *Equatorial Zone.*—Generally very white with no trace of yellow, the brighter spots being an almost phosphorescent white. After July the brightness of the *S. edge* (G) faded considerably and became slightly shaded (the motion of this is dealt with under S. Equatorial Belt). The *N. edge* of the zone (K) was very bright throughout, always the brightest part of the disc. The brightness was remarkably uniform, and its regularity was shared by the S. edge of N. Equatorial Belt.

This region is always subject to great variations, probably cyclical, the markings being sometimes as frequent and well marked as those of the S. edge of Equatorial Zone, while at other times they completely disappear. I cannot say whether this is due to an actual cessation of activity in the spots themselves or to the interposition of some obscuring medium between our eye and the strata in which the spots occur. It appears to vary in some way with the breadth and distinctness of the N. Equatorial Belt.

(*L*) *N. Equatorial Belt.*—Its appearance in 1903-4 was most peculiar. A faint orange band was visible throughout in its position, on the *S. edge* of which lay a very narrow dark uniform purple band, containing practically no darker knots or condensations. The tint of this S. streak grew gradually warmer and browner towards the end of the apparition. Along the *N. edge* of the faint orange band was a very faint streak, continuous on the finest nights, but generally barely traceable. Here and there in this streak were short intensely dark portions, sharp and well

defined, but fading later in the apparition. Their period ($9^h\ 55^m\ 29^s{\cdot}90$) agrees well with previous years, but as usual there are traces of abnormally rapid period in a few spots.

(*M*) *N. Tropical Zone.*—Always whitest along its N. edge, where it was sometimes very bright; but the general tint was brownish yellow, browner and yellower to S. A few diffuse white spots were seen early in the apparition in the northern part of the zone, but faded very much as time went on. Their period is remarkably uniform, and is identical with that of the short dark streaks in N. edge of N. Equatorial Belt, with which they are obviously connected.

(*MM*) *N. Tropical Belt.*—A decided bluish-grey belt having at times a peculiar, almost mauve, tinge. Some of the streaks in it are certainly double. It joins the S. edge of a very faint grey shade which extends to the N. pole. The motion of the markings in it, as in recent years, was very irregular. The mean period ($9^h\ 56^m\ 01^s{\cdot}94$) is very slow, but agrees well with the figures obtained in 1899 and 1900. The period in different years appears to depend on the varying latitude of the belt.

(*NN*) *N. Temperate Zone.*—More variable in brightness than any of the other zones. The brighter patches being vague and nebulous, with the exception of two fairly distinct spots in $\lambda 343°$ and $359°$. The average period ($9^h\ 55^m\ 56^s{\cdot}11$) agrees well with previous results and appears reliable.

(*N*) *N. Temperate Belt.*—Faint bluish, generally greyer in tint than N. Tropical Belt. The spots in it give an average period of $9^h\ 55^m\ 41^s{\cdot}05$, but their motion is very irregular. The measures show a considerable displacement in latitude to the N. late in the apparition, which may account for this irregularity.

(*P*) *N.N. Zone.*—Faint and nebulous, but fairly uniform. The periods obtained for this zone in different years do not agree, and cannot be regarded as reliable.

(*Q*) *N. Polar Region.*—Generally slightly striated, with a faint bluish tinge, the S. edge being rather the darker. The mean period for spots in it is $9^h\ 55^m\ 21^s{\cdot}49$, agreeing with that obtained in 1900, but differing considerably from that for 1901. Just inside the darker border of the polar regions is a very faint zone (R), and a very faint diffuse belt (S) further N. No results could be deduced from the scattered observations of spots in these latitudes.

General Tint of Planet.—The general tint in 1903–4 was unusually white, with hardly any trace of yellow. Even with the naked eye the planet seemed a paler yellow than usual.

Relative Brightness of Zones.—The relative brightness of the various zones was noted each night, the brightest zone being numbered 1 and the others in order. A rough measure of the relative brightness has been obtained by adding all the "points"

r and dividing by the number of observations. T
are as follows :—

	N. edge of Equatorial Zone	1·02
	S. " "	2·10
	S. Tropical Zone	2·88
n.	N. edge of N. Tropical Zone	3·48
N.	N. Temperate Zone (very variable) ...	4·66
	S. Temperate Zone	5·25
	N.N. Zone	6·37
	S.S. Zone	8·00

asures.—Six sets of measures were made in 1903 M
ree in December. The results in each case are redu
ance from the centre at mean distance of *Jupiter* (5·2
ans of each group are then reduced to apparent latitu
rrected for the tilt of axis. In the reduction no accou
n taken of polar compression, the formula employed bei
= d/r where d = distance from centre and r = polar rad
ter.

This agrees fairly with Barnard's measures (*Monthly Notices*, vol. lviii. p. 217)

i. = $1''\cdot048$ ii. = $0''\cdot874$ iii. = $1''\cdot521$ iv. = $1''\cdot430$

Albedo.—ii. has a peculiar sheen and almost sparkles, with evidently a very high albedo. I never remember a case of a dark transit of this satellite.

i. has a soft steady light, but is decidedly less reflective than the centre of *Jupiter*, generally grey in mid-transit.

iii. shines with a very soft, equable light, like i., but its albedo is decidedly lower; as it is grey for the greater part of its transit, even in high latitudes, and very dark at mid-transit.

The albedo of iv. is very low indeed, and its surface seems slightly less reflective than the limb of *Jupiter*. It appears grey directly after transit ingress, and is almost black at mid-transit.

Colour.—The average colours to my eye are :—i. very pale yellow, with sometimes a faint rosy tinge; ii. more decided yellow than i.; iii. very pale primrose yellow paler even than i.; iv. bluish or purplish when faintest, greyish white when brightest.

Variability.—Very difficult to estimate. iv. and ii. appear to have the greatest range; i. only very slightly variable; iii. remarkably uniform.

Effect of glare, &c.—iv. and ii. also appeared more affected by twilight and the glare of the planet, and also by haze and cloud, than the other two (a curious result, considering their utter dissimilarity in size, albedo, and colour).

To sum up, if we use the same convention I have adopted for the satellite comparisons, the relative values come out as follows :—

General brightness : iii. (1 +) ; i. (2 —) ; ii. (3) ; iv. (4).
Albedo : ii. (1 +) ; i. (2 —) ; iii. (3 +) ; iv. (4).
Size : iii. (1) ; iv. (2 +) ; i. (3) ; ii. (4).
Colour : iii. palest yellow ; i. pale yellow ; ii. yellowest ; iv. bluish.
Variability : iv. (1) ; ii. (2 +) ; i. (3 —) ; iii. (4).
Affected by glare, &c. : iv. (1) ; ii. (2 +) ; i. (3) ; iii. (4).

An earlier comparison of mine is given in *B.A.A.J.* (ix. 432).

Apparent Elongation of i.—The apparent elongation of i. in transit near ingress and egress was repeatedly noticed. The phenomenon is most marked at ingress. It is certainly due to the higher albedo of the equatorial portion of the satellite disc (*Mem. B.A.A.* vii., iv. 99).

pses of ii.—The somewhat rare phenomenon of an eclip
st clear of occultation was seen on three occasions
On June 6 the observed interval between Ec.R. a
was 2^m 55^s against 1^m 06^s predicted in *N.A.*
er 1 the observed interval between Oc.R. and Ec.
58^s against 1^m 37^s predicted, and on December 8, 6^m
3^m 29^s predicted; so that the observed times in eve
re considerably in excess of the predicted times.
bb (*Celestial Objects*, i. 180) speaks of only four instan
n record. This is surely a mistake, as I think I ha
witnessed eight or ten cases.

kings on iii.—Markings were seen on the disc of
transit on several occasions. If the satellite is careful
d just as it appears to turn grey, the equatorial markin
distinctly seen, if the conditions are good, with a pow
or 450.

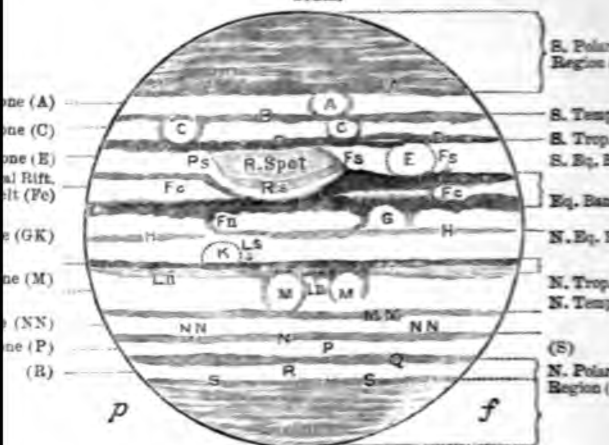
tortion of Shadows near Quadrature.—The distortion
dows at ingress and egress near quadrature was well se
eral occasions. In poor seeing the effect of the E.-
ion is to make the shadow appear larger and dark
he reversed conditions make it seem very small and fai
l air, however, the elongation can be distinctly seen, b
seems to attain the magnitude demanded by theory.

There is an unmistakable cyclical "swing" in period, of variable magnitude and duration; but I cannot determine its cause, or the laws which govern its action. It may possibly be due to tidal action of the four larger satellites, the apparent irregularity depending on the varying configurations of the four. I should be very glad if some one, with more leisure and mathematical ability than I have, would thoroughly investigate the question. My observations would, I believe, give sufficient data to work on, and I should be delighted to place them at his disposal. A few years ago, from the movements of the two shoulders of the Red Spot Bay, I was led to strongly suspect a period of ± 90 days between maximum variations, but I have been unable to confirm this since.

Possible Extension of the Atmosphere of Jupiter.—I have carefully studied the behaviour of the satellites this year when close to *Jupiter*. The glare of the planet undoubtedly affects the brightness of the satellite considerably, and the different satellites are affected in different degrees. Estimations of this sort are particularly liable to error, but the observations this year confirm those of previous years, and tend to show that the satellites are very much fainter near occultation than when in similar positions with respect to *Jupiter* near transit, often losing fully half their light. The difference is most striking with ii. Near transit this satellite is very brilliant, but near occultation seems often hardly brighter than the limb. The evidence is rather conflicting, but seems to point to the existence of an invisible atmosphere round the planet, which extends some distance from the apparent limb. The idea is not new, and the explanation seems rational when we consider the probable high temperature of the planet.

Visibility of the Red Spot Bay.—For several years I have made a practice of noting the visibility of the Red Spot bay at varying distances from the C.M. when coming on and passing off. The observations agree very well, and tend to show that the following shoulder is more easily visible coming on than passing off, while the reverse is the case with the preceding shoulder. Coming on, the following shoulder is visible under favourable conditions when 70° of longitude from the C.M.; while passing off it has already begun to be very nebulous and indistinct before it reaches 60° from the C.M. The preceding shoulder, on the other hand, is very hard to see coming on until less than 50° from the C.M.; while passing off it can sometimes be traced almost to the limb, and clearly to 65° or more of longitude from C.M. The shade of the Red Spot itself is more apparent when coming on and going off than when it is actually on the central meridian. This latter phenomenon is possibly due to the surface of the spot consisting of slightly roughened cloud masses, which introduce slight shadow effects when obliquely lighted, thereby increasing the apparent darkness of the spot. When near the C.M. the illumination would be

vertical, and the shadow effects would disappear.
d a diagram showing the nomenclature adopted and t



NOMENCLATURE DIAGRAM.

No. of Spots.	Average No. of Rotations.	Average No. of Observations.	Period.	No. of Spots.	Average No. of Rotations.	Average No. of Observations.	Period.	No. of Spots.	Average No. of Rotations.	Average No. of Observations.	Period.
	1898.				1899.				1900.		
			h m s				h m s				h m s
...	...	...	...	...	...	...	...	22	614	15·0	9 50 29·04
...	...	...	...	10	183	5·0	9 55 35·01	10	562	25·1	9 55 29·18
6	196	11·1	9 55 26·67	21	171	6·7	9 55 30·83	20	612	35·0	9 55 30·47
...	...	...	...	...	...	...	...	6	646	39·5	9 55 21·46†
...	...	...	...	6	123	4·5	9 56 6·41	13	496	17·1	9 56 0·21
...	...	...	...	...	...	...	...	5	307	7·2	9 55 58·97
2	123	7·0	9 55 50·65	5	173	4·4	9 56 17·54?	14	430	11·0	9 55 37·92
...	...	...	...	...	...	...	...	5	284	5·8	9 55 35·21
...	...	...	...	...	...	...	...	4	517	12·7	9 55 19·12

No. of Spots.	Average No. of Rotations.	Average No. of Observations.	Period.	No. of Spots.	Average No. of Rotations.	Average No. of Observations.	Period.	No. of Spots.	Average No. of Rotations.	Average No. of Observations.	Period.
	1901.				1902–3.				1903–4.		
4	421	6·2	9 55 22·75	...	...	...	...	4	432	52·0	9 55 14·24
5	380	7·2	9 55 19·88	1	567	4	9 55 36·95?	2	593	16·0	9 55 5·16
21	525	11·2	9 55 6·14	3	635	7·7	9 55 4·01	9	569	16·0	9 55 6·35
								5	649	16·6	9 55 12·25†
22	526	12·3	9 55 18·26	2	142	6·5	9 55 18·84	12	686	30·4	9 55 19·03
25	514	12·0	9 55 17·76	7	564	7·3	9 55 17·88	17	658	27·6	9 55 18·45
...	...	...	...	...	...	...	...	8	357	17·3	9 55 48·47
3	633	29·0	9 55 40·63	3	752	20·7	9 55 39·70	3	714	44·7	9 55 41·19
1	611	29·0	9 55 19·33	4	689	18·0	9 55 14·42	4	716	49·5	9 55 21·83
				4*	540	...	9 55 21·15				
20	492	9·6	9 51 32·29	...	...	...	...	16	599	10·4	9 51 27·19
56	539	15·3	9 50 25·89	18	673	9·5	9 50 25·90	42	685	25·0	9 50 22·72
9	464	7·0	9 50 27·98	...	...	...	...	18	552	7·6	9 50 24·89
44	519	8·3	9 50 25·29	3	700	12·0	9 50 41·97	2	597	6·0	9 50 49·06?
28	532	11·2	9 55 29·72	13	597	9·3	9 55 26·72	13	570	27·0	9 55 29·90
9	527	6·7	9 55 39·29?	2	434	7·0	9 55 50·76	11	495	13·2	9 56 1·54
2	570	7·0	9 55 56·27	...	...	...	...	18	545	9·7	9 55 55·11
16	478	9·4	9 55 42·88	1	666	9·0	9 55 50·55	19	618	18·2	9 55 41·05
13	477	7·7	9 55 37·80	...	...	...	...	12	478	7·9	9 55 39·93
21	458	8·4	9 55 39·66	...	...	...	...	11	411	11·6	9 55 21·49

"G. S. T." = Great South Tropical Dark Area.

* Intermediate period, 1903 January–April. † Abnormal.

TABLE II.

Measures 1903–4.

Date. 1903.	Approx. G.M.T.	Power.	Definition.	Approx. Longitude (System II.).	Distance from Centre at Mean Distance 5·20. Centre S. Tropical Belt (D).	S. Edge of S. Equatorial Belt (Fs).	N. Edge of S. Equatorial Belt (Fn).	S. Edge of N. Equatorial Belt (Ls).	N. Edge of N. Equatorial Belt (Ln).	Centre N. Tropical Belt (MM).	Centre N. Temperate Belt (N).	Polar Diameter. Observed (O).	Calculated (C).	O–C.	Reduced to Distance 5·20.	O–C.
May 12	12·47	280	good to sharp	320°	− 7″·660	− 4″·758	−2″·310	+1″·862	+ 3″·698	+ 7″·186	″ ...	″ ...	″ ...	″ ...	″ ...	″ ...
19	12·40	280	sharp	285	− 7·826	− 6·056*	−2·158	+2·009	+ 2·946	+ 7·160	+ 9·689	...	...	...	...	...
21	12·27	280	sharp, falling off	217	− 7·964	− 5·159	−2·759	+1·778	+ 3·570	+ 6·823	+ 9·482	36·02	35·66	+0·35	36·311	+0·366
25	12·40	280	"	108	− 8·620	− 5·090	−2·520	+2·040	+ 3·770†	+ 7·530	...	36·36	36·06	+0·30	36·241	+0·296
26	12·33	280	sharp	253	− 8·674	− 5·419	−1·990	+2·094	+ 3·552	+ 7·210	+10·111	36·47	36·22	+0·25	36·246	+0·301
27	12 40	205	sharp, falling off	48	...	− 4·730	−2·192	+1·702	+ 3·529	+ 7·262	...	36·71	36·39	+0·39	36·378	+0·433
May Observations (micrometer).	Means ...	...	..		− 8·149	− 4·934	−2·320	+1·914	+ 3·459	+ 7·195	+ 9·761			Mean ...	36·294	+0·349
	Apparent latitude			...	S. 26°·97	S. 15°·93	S. 7°·42	N. 6°·12	N. 11°·10	N. 23°·60	N. 32°·90					
	Correction to centre (B)				+ 1·52	+ 1·52	+1·52	+1·52	+ 1·52	+ 1·52	+ 1·52					
	True latitude (φ)			...	S. 25·45	S. 14·41	S. 5·90	N. 7·64	N. 12·62	N. 25·12	N. 34·42					
Dec. 1	0 00	280	good, improving	115″	− 8″·220	− 5″·800‡	−2″·790	+1″·560	+ 3″·380	+ 7″·030	″ ...	38″·93	39″·28	+0″·35	35″·621	−0″·324
7	0·00	205	"	297	− 8·290	− 4·626	−2·431	+1·717	+ 3·910	+ 8·279	...	38·45	38·51	−0·06	35·888	−0·057

* In dark area. † Detached streak. ‡ Near dark area.

Date. 1903.	Approx. G.M.T.	Power.	Definition.	Approx. Longitude (System II.).	Distance from Centre at Mean Distance 5·20. Centre S. Tropical Belt (D).	S. Edge of S. Equatorial Belt (Fs).	N. Edge of S. Equatorial Belt (Fn).	S. Edge of N. Equatorial Belt (Ls).	N. Edge of N. Equatorial Belt (Ln).	Centre. N. Tropical Belt (MM)	Centre. N. Temperate Belt (N).	Polar Diameter. Observed (O).	Calculated (C).	O–C.	Reduced to Distance 5·20.	O–C.
Dec. 19	0·05	205	good, improving	302°	− 8″·822	− 4″·932	−2″·384	+2″·063	+ 3″·751	+ 8″·308	+12″·228?	37″·08	37″·07	+0″·01	35″·954	+0″·009
		Means		...	− 8·444	− 5·119	−2·535	+1·780	+ 3·680	+ 7·872	+12·228?			Mean ...	35·821	−0·124
December Obs. (micrometer).		Apparent latitude		...	S. 28°·03	S. 16°·55	S. 8°·12	N. 5°·68	N. 11°·82	N. 25°·97	N. 43°·00					
		Correction to centre (B)			+1·61	+ 1·61	+1·61	+1·61	+ 1·61	+ 1·61	+ 1·61		Mean of both ...		36·091	+0·146
		True latitude (φ)		...	S. 26·42	S. 14·94	S. 6·51	N. 7·29	N. 13·43	N. 27·58	N. 44·61					
												N. Edge of S. Polar Region (AA).		Centre of S. Temp. Belt (B).		S. Edge N. Polar Region (Q).
Oct. 19	2·05	270 (eye estimate)	sharp	200°	− 9″·113	...	...	...	...	+ 7″·702	+10″·810	−13″·520		−12″·567		+13″·397
October (eye estimate.)		Apparent latitude		...	S. 29·65	...	...	...	...	N. 25°·37	N. 36°·93	S. 48°·68		S. 44°·07		N. 48°·24
		Correction to centre (B)			+ 1·77	...	...	...	...	+ 1·77	+ 1·77	+ 1·77		+ 1·77		+ 1·77
		True latitude (φ)		...	S. 27·88	...	...	...	...	N. 27·14	N. 38·70	S. 46·91		S. 42·30		N. 49·99
		Adopted Mean latitude		...	S. 25·93	S. 14°·67	S. 6°·20	N. 7°·46	N. 13°·02	N. 26·61	...	S. 47·0		S. 42·3		N. 50·0

Trincomali, Ceylon:
1905 *April* 10.

A Suspected Instance of Sudden Change on Jupiter.

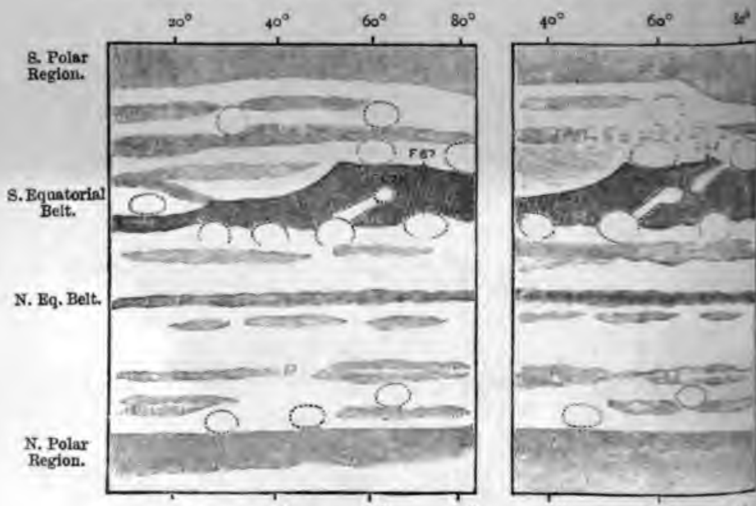
By Major P. B. Molesworth, R.E.

A most curious and unique observation was made here 1903 December 17.

I quote from the observing notes :—

"The dark spot F87 (in the S. edge of S. equatorial belt) crossed the C.M. under almost perfect definition at $7^h\ 10^m{\cdot}5$ L.T. ($1^h\ 45^m{\cdot}5$ G.M.T.). The surroundings were carefully entered on the sketch (No. 128) and the neighbourhood presented the appearance shown there.

"At $7^h\ 25^m$ L.T. (2^h G.M.T.) I suddenly noticed a minute bright white spot, like i just after ingress, on the S. edge of the S. equatorial belt immediately preceding F87. I thought it very strange that I should have omitted to take the transit of such a prominent spot or to show any indication of it on the sketch. At $7^h\ 28^m$ L.T. ($2^h\ 03^m$ G.M.T.) it was



No. 128.—Longitude (System II.). About 1·45 G.M.T.

No. 128 a.—Longitude (System II.). About 2·05 G.M.T.

very evident, and could not have escaped the most casual scrutiny. Between $7^h 25^m$ and $7^h 30^m$ L.T. (2^h—$2^h 05^m$ G.M.T.) its visibility fluctuated a good deal. This was not due to any fault in the definition, which was very sharp the whole time. By $7^h\ 30^m$ L.T. ($2^h\ 05^m$ G.M.T.) the bright spot had extended as a short bright rift for some distance into the belt, its north preceding end being only separated by a

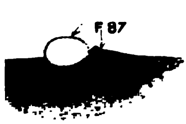
narrow streak from F83. This appearance was preserved unchanged as far as I could see till $7^h\ 50^m$ L.T. ($2^h\ 25^m$ G.M.T.), but the region was then so far from the C.M. as to make observation difficult. When the bright spot was first noticed, it was just *preceding*, and in contact with, F87; but the oblique rift later on appeared to enter the belt from a point immediately *following* F87.

"I am certain that there was no illusion in the question, and that the phenomenon was a case of actual rapid change on the surface of *Jupiter*. I have tried to represent the general appearance after the formation of the spot at $7^h\ 30^m$ L.T. ($2^h\ 5^m$ G.M.T.) in No. 128a, and the change can be easily seen by comparison with No. 128, which shows the same neighbourhood at about $7^h\ 10^m$ L.T. ($1^h\ 45^m$ G.M.T.)."

The telescope used was the 12¼ Calver reflector with a einheil monocentric eyepiece magnifying 270.

During a fairly large experience of work on *Jupiter* I have ver seen anything in the remotest degree like the appearance corded in this observation, and I am perfectly certain that ere was no illusion.

The apparent change of position of the white spot with regard the dark spot F87 is, I think, attributable to an actual motion the white material diagonally across the belt; forcing back e dark edge of the belt in its onward progress, and curling it er so as to form a second and darker inflection of the S. edge the belt just following F87, which was mistaken for F87, mewhat as shown in the three diagrammatic sketches (figs. 1 3). In these the arrow shows the direction of motion of the hite material under this supposition. I have purposely exaggrated the size of the second inflection.



1. About $2^h\ 00^m$.

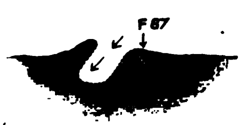


Fig. 2. About $2^h\ 03^m$.

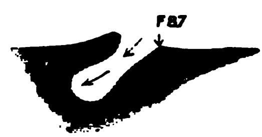


Fig. 3. $2^h\ 05^m$ and later.

It will be noticed that the outburst took place a short disnce following the Red Spot bay in a latitude where rifts of is sort are practically unknown. I cannot recollect ever ving seen a rift connecting the S. tropical zone with the ntral rift of the S. equatorial belt, but connections between e central rift and the S. edge of equatorial zone are very mmon. The outburst is therefore peculiar from its position as ell as on account of its suddenness.

The same region was visible in twilight on 1903 December 20, t no signs of the formation could then be seen, nor was

anything remarkable noticed in its position at any subsequent date. Its existence seems therefore to have been a very short one.

Of the two sketches forwarded, No. 128 is a portion of the ordinary eyepiece chart for the night's work. No. 128a is a copy of the sketch made after the appearance of the spot in the observing note-book, the neighbourhood being filled in from No. 128.

Trincomali, Ceylon:
1905 *April* 12.

Further Note on the Density and Prolateness of close Binary Stars. By Alex. W. Roberts, D.Sc.

In vol. lxiii. (p. 527) of the *Monthly Notices* I considered the problem of determining the orbital elements of a close binary system from the light-changes produced by the mutual eclipse of the component stars as they circled round one another.

It is indeed only from photometric observations that we may hope to determine what many would regard as two of the most important facts in cosmic physics, the density of structure and the prolateness of figure of two masses of matter revolving almost, or actually in contact, round their common centre of gravity.

Fortunately the difficulty of the problem, at least when considered generally, is not in any way a serious one. The problem consists, in its simplest form, in determining the area of the projected surface of two contiguous revolving masses. The light-changes of a close binary system are of course dependent on this ever-changing area. Given, therefore, a very accurately determined light-curve, we may readily ascertain the area included within the projected outline of the system; and this being known, it is but another step to the determination of the orbital elements, of figure, of position, of movement, which govern the form of the projected area.

This of course is only a general statement of the problem. A rigorous consideration of it is a more involved matter. We may indicate one or two of the difficulties that arise.

If the orbit of a close binary system be at all eccentric, and the density small, as is usually the case with stars of this class, then there will be a constant change of figure as the mutual attraction varies in intensity. To give a concrete example, the major axis of β *Lyræ* varies in length every revolution, through at least one million miles, and this contraction and expansion along the major axis, and commensurate expansion and contraction along the two axes at right angles to it, is a continuous movement. Further, the turning points of this oscillation do not coincide with the apsidal line, but are modified by the density

and rigidity of the system, that is, by its power to adapt itself readily to the ever-changing forces acting upon it.

Then again this constant change of figure of such systems as are eccentric in orbit must produce a constant alteration in the surface pressure of the system, and this variation will naturally display itself in minute yet measurable light-changes.

These subordinate fluctuations of figure, pressure, light, and heat, are represented in every carefully determined light or motion curve. They appear as some of the contradictions and aberrations which either the spectroscope or the photometer reveals to us with regard to such stars as *β Lyræ*, *V Puppis*, and *RR Centauri*.

And in this connection I would strongly urge a constant watch being kept on stars of this class, for while the *mean* light-curve of a close binary star remains unchanged, each group of observations yields departures from this mean curve that are significant and important.

Every observer who has made extensive photometric observations of any single Algol binary star knows how dissimilar in points of detail, yet similar in their general family type, are the various curves obtained by grouping observations in sets. To give again a concrete example, let the light-curves of *β Lyræ* as determined by Goodrick (*De stella β Lyræ variabile*, p. 22); by Argelander (*De stella β Lyræ variabile*, commentatio altera, p. 28); by Schur (*Ast. Nac.* No. 3283); by Markwick (*Memoirs British Astron. Assoc.* vol. xi., pt. 4) be compared and the want of complete correspondence between the light-curves of *β Lyræ* taken at wide intervals of time will be at once evident.

Yet this lack of agreement is a much more significant fact in stellar physics than any apparent and unreal agreement would be. The want of complete correspondence between the curves indicated above (of *β Lyræ*) is due to, and is therefore a measure of, the changes produced (1) by the steady recession from one another of the component stars forming *β Lyræ*; (2) by the evolution of the apsides of the system.

The former needs no proof, merely a presentment of the fact, as the regular but ever-diminishing increase of period of *β Lyræ* is one of the firmly established facts of astronomy; while the second—the revolution of the apsidal line of *β Lyræ*—is made evident by a critical examination of the various light-curves.

Yet while the deeper problems that gather round these remarkable stars can only be dealt with fully when we have a long and continuous series of observations to work upon, some of the more salient points of figure and density are readily deducible from a single light-curve, obtained even from a few but well-placed observations.

I think it will be admitted that two outstanding facts of figure and density are (1) that there is a certain definite correspondence between prolateness and distance, and (2) that the density of all close binary stars is small.

Every addition to the number of close binary stars confirms these two conclusions.

The last star added to the list, *V Vulpeculæ*, also raises two points of extreme interest in any investigation dealing with stellar evolution; and since these two matters can be satisfactorily considered from a single determination of the light-curve of the star, I think the present not unfavourable for an inquiry into their meaning and force.

The light-curve that we use as *datum* for our conclusions was deduced by Mr. Stanley Williams from observations made by himself.

The light-curve, and certain interesting matter concerning it, finds a place in the *Journ. British Astron. Assoc.* vol. xv. p. 200.

The light-curve yields the following elements of variation of *V Vulpeculæ*:

Period	75·3 Days
Mag. at max.	8·21
Mag. at prin. min.	9·65
Mag. at sec. min.	8·66
Duration of prin. eclipse...	22 Days
Duration of sec. eclipse	18 "
Duration of non-eclipse period	35 "

We use the term "non-eclipse" period instead of "constant" period for a reason that will appear later on.

In order that the proof of the prolateness of the two stars that go to make up the binary system *V Vulpeculæ* may be as convincing as possible, let it be assumed that they are spheres.

From the conditions of the problem, it is evident that during the period of non-eclipse we see both stars; that is, 8·21 mag. represents the combined light of both components, V_1 and V_2. Let this quantity of light be regarded as equal to unity.

During principal minimum V_2 eclipses V_1, causing a decrease in brightness of 1·44 mag.; that is, the light falls from unity to 0·26.

At the secondary minimum, V_1 eclipses V_2, causing a decrease of 0·45 mag., or a fall from unity to 0·66.

We have accordingly the following relations:

$$L_1 + L_2 = 1{\cdot}00$$
$$L_1 + mL_2 = 0{\cdot}66$$
$$L_2 + nL_1 = 0{\cdot}26$$

where L_1 and L_2 represent the light of the components V_1 and V_2, and m and n are positive proper fractions, or zero. They represent the uneclipsed portions of V_2 and V_1.

From the above equations there results the identity

$$m = \frac{8 + 66n}{100n - 26}$$

It is evident that any fractional values of n make m greater than unity or a negative quantity—an impossible condition.

The two stars, therefore, which compose *V Vulpeculæ* cannot be spherical.

This conclusion is further borne out by the bow-shaped form of the curve during non-eclipse period. If the component stars were spheres the light-curve during the time of non-eclipse would be a *straight line*. The arched form, however, indicates a changing projected surface, such as that of a prolate spheroid revolving round its minor axis.

We now proceed to deal with the amount of this prolateness.

The equations that connect light-variation with the orbital elements of a close binary system are given in *Monthly Notices*, vol. lxiii. pp. 532–534, and so need not be stated again.

Put briefly the relations are, in the case of *V Vulpeculæ*:

$$1{\cdot}00 = L_1 + L_2$$

$$0{\cdot}66 = L_1 \sqrt{1 - \cos^2 \iota\epsilon^2}$$

$$0{\cdot}26 = L_2 \sqrt{1 - \cos^2 \iota\epsilon^2}$$

Regarding now the eclipse as a central one, that is, $\cos^2 \iota = 1$, there result the following values:

$$L_1 = 0{\cdot}72$$

$$L_2 = 0{\cdot}28$$

$$\epsilon = 0{\cdot}39$$

The quantity ϵ is the eccentricity or prolateness of the figure of the component stars of the system; that is, *V Vulpeculæ* is composed of two nearly equal masses, one of which is two and a half times brighter than the other.

The prolateness or eccentricity of figure is 0·39.

The duration of eclipse when compared with the full period of revolution yields the relative size of the component stars.

Without going into the numerical operations we find that, taking the radius of the orbit of the system as unity, the major radius of either star is 0·38; that is, the gap between the stars forming the system of *V Vulpeculæ* is only 0·24 in width, the radius of the orbit being unity.

These results when related to similar determinations already obtained are, we venture to think, of some importance in the study of the evolution of binary systems.

In *Monthly Notices*, vol. lxiii. p. 527, I carried out a rigorous determination of the figure and density of the close binary star *RR Centauri*, finding for this system a prolateness of 0·78 and a

e between the components of $-0·01$, that is, they
contact.

he *Astrophysical Journal*, vol. vii. p. 1, Mr. Myers d
e binary system *β Lyræ*, finding a prolateness of
t the stars had just separated.

ing the past four months I have had under considera
lines of the present investigation, the variation of *β L*
from a discussion of all available observations a
icity of figure equal to 0·58, and a mean distance (for
o 0·01.

cing these results in tabulated sequence we have :

System.	Distance between Components.	Prolateness according to Observation.	Prolateness according to Theory.
R Centauri	$-0·01$	0·78	0·66
Lyræ	$+0·01$	0·57	0·58
V Vulpeculæ	$+0·24$	0·37	0·35

conclusion here is evident and unmistakable. *The ne*
ponents are to one another the greater their prolate
e amount of prolateness is in fair conformity with
alone would indicate.

density of *V Vulpeculæ* raises another and perhaps
ant issue

pairs have been included, as they are not found in any catalogue so far as I am aware; but as they are all marked as double in Argelander they have not been numbered.

No.	B.D.	R.A. 1880 h	m	Decl. °	'	P. °	D. "	Mags.		Nights.	Date.	
151	+39°12	0	2·5	+39	58	196·0	6·4	8·6	12·8	2	04·85	
152	+39·27		7·1	39	33	102·7	7·8	8·5	12·0	3	05·02	
153	+40·42		10·2	40	37	243·1	2·5	9·5	10·5	2	04·73	
154	+53·54		16·2	53	40	191·7	10·2	8·4	9·3	3	02·91	
155	+36·173		52·8	37	7	70·4	6·2	8·7	9·6	2	05·05	
156	+53·234	1	2·5	53	59	216·5	5·2	8·6	11·8	3	03·91	
157	+40·250		6·7	40	31	*f*	10±	7·0	13·5	2	04·86	
158	+40·378		42·1	40	22	45·0	6·6	8·5	9·8	1	05·02	
159	+37·386		45·1	37	11	...	5±	8·7	14·0	1	04·76	
160	+36·355		49·0	36	40	79·8	17·9	5·2	12·5	2	04·73	
161	+37·420		49·6	37	14	243·4	3·9	9·5	10·7	3	04·77	
162	+36·369		50·6	36	10	204·1	11·1	8·7	12·5	3	04·85	
163	+36·375		50·9	36	11	15·9	5·5	9·4	9·9	3	04·85	
164	+40·475	2	10·6	40	19	...	5±	8·7	13·0	1	05·02	
165	+63·435	3	28·1	63	49	171·9	3·7	9·9	10·4	3	04·05	
166	+39·844		33·7	39	19	357±	4±	8·5	13·0	1	05·02	
167	+34·730		39·8	34	58	322·6	4·4	9·0	9·1	3	04·86	
168	+36·868	4	11·8	36	26	273·2	6·7	8·5	11·5	3	05·16	
...	+59·793		12·7	59	20	58·9	32·1	6·0	8·8	1	04·07	
169	+39·1191	5	0·6	39	20	176·5	4·5	8·3	12·0	2	05·03	
170	+34·978		7·8	34	17	23·4	12·7	8·0	10·1	2	05·16	
171	+62·756		18·5	62	35	222·9	2·3	8·7	10·5	1	04·06	
172	+39·1397		36·6	39	47	135·4	4·9	9·0	10·0	1	05·02	
173	+39·1404		37·7	39	10	N.F.	4±	8·5	12·5	1	05·03	
174	Anon.	6	27·9	36	55	108·7	3·0	9·6	9·8	2	05·10	
175	+36·1498		38·0	36	35	79·4	6·4	8·9	9·4	1	05·10	
176	+34·1451		38·3	34	26	70±	6±	8·8	12·0	1	05·15	AB
						45±	6±		12·5	1	05·15	AC
177	+37·1582		38·8	37	4	...	6±	9·5	10·5	1	05·07	BC
							70±	A = 8·5		1	05·07	AB
178	+40·1776		53·5	40	1	247·7	6·6	9·5	11·5	2	00·51	BC
						151·3	8·5	A = 9·4		2	00·51	AB
179	Anon.	7	49·0	38	2	...	4±	9·5	9·5	1	05·07	
180	+36·2033	10	1·5	36	10	349·6	9·6	9·0	11·0	1	05·25	
181	+36·2166	11	6·6	36	22	142·9	5·4	9·1	10·7	3	05·29	
...	+34·2264		44·9	33	54	273·7	45·2	6·0	8·5	2	05·34	

No.	B.D.	R.A. 1880 h	m	Decl. °	′	P. °	D. ″	Mags.		Nights.	Date.	
182	+63°1346	17	21·4	63	51	19·1	6·5	9·0	11·5	4	03·60	
183	+36·3026	18	4·7	36	41	163·0	9·8	8·7	12·0	3	04·74	
184	+32·3056		4·7	32	54	157·2	5·5	9·0	11·2	2	04·73	
185	+32·3064		6·6	32	57	296·6	5·5	8·8	9·4	4	04·76	
186	+64·1256		15·6	64	1	332·7	8·6	8·2	12·0	2	03·61	
187	+51·2372		20·9	51	35	198·7	2·7	8·6	8·7	4	03·76	
188	+58·1824		31·5	58	36	224·8	11·7	8·2	13·7	2	02·81	
189	+60·1844		42·4	60	32	103·6	4·3	9·1	11·1	1	03·88	
190	+33·3228		46·1	33	4	236·0	4·2	11·5	12·0	3	04·62	BC
						295·1	12·9	A = 9·5		2	04·61	AB
191	+61·1816	19	5·2	61	4	243·9	6·1	9·1	9·8	1	03·60	
192	+59·1979		12·7	59	33	116·3	7·4	9·0	11·6	2	03·63	
193	+59·1981		13·3	59	34	113·7	8·1	8·8	11·7	2	03·63	
194	+64·1346		20·2	64	18	216·3	4·4	8·8	9·9	3	03·68	
195	+33·3496		27·9	34	2	239·5	5·6	8·3	9·0	4	04·75	
196	+32·3467		28·5	33	3	48·7	4·5	9·0	12·0	1	04·69	
197	+64·1364		35·6	64	47	19·3	8·9	8·5	10·5	3	03·68	
198	+64·1369		37·8	64	39	313·7	2·7	8·8	9·4	3	03·68	
199	+64·1386		46·3	64	23	70·7	6·5	8·0	10·5	1	03·88	
200	+34·3791		50·7	34	15	229·0	4·5	10·0	10·0	2	04·75	
201	+59·2160		57·3	59	25	145·0	4·1	9·0	11·5	1	03·64	
202	+34·3850		57·9	34	59	180 ±	6 ±	8·7	14·0		04·83	Aa
						100·0	17·3	B =	10·5	3	04·83	AB
						110·7	5·5	*b*	13·0	2	04·86	Bb
						162·8	12·3	C	11·5	2	04·86	AC
						134·8	23·6	D	11·8	2	04·86	AD
203	+35·3983	20	3·8	35	7	131·4	5·8	8·5	10·0	2	04·94	
204	+34·3930		9·7	35	1	238·4	11·0	8·1	12·0	2	04·66	
205	+34·3936		10·4	34	38	195·5	6·6	8·8	10·7	2	04·95	
206	+37·3949		24·3	37	47	127·1	4·1	8·9	9·3	2	04·79	
...	+57·2240		42·5	57	9	162·7	68·6	5·0	8·7	3	02·83	
207	+37·4213	21	6·4	37	51	244·3	2·5	9·5	9·6	1	04·95	
208	+36·4469		8·5	37	4	143·0	3·7	8·8	10·7	2	04·82	
209	+52·2883		8·7	52	48	...	4 ±	9·0	12·0	1	03·69	
210	+32·4270		44·5	32	47	111·4	6·5	9·2	10·5	2	04·82	
211	+39·4683		45·6	39	11	196·9	2·6	9·5	10·5	1	04·77	
212	+64·1608		53·0	65	5	Double	...	9·0	...	1	03·60	
213	+63·1814	22	5·8	63	31	...	4 ±	9	11	1	03·60	
214	+34·4634		10·1	34	11	170·4	3·5	9·0	12·0	1	04·69	

No.	B.D.	R.A. 1880	Decl.	P.	D.	Mags.		Nights.	Date.
	°	h m	° ′	°	″				
215	+34·4635	10·2	34 18	141·7	8·8	8·8	12·5	1	04·69
216	+35·4850	32·3	36 4	...	4±	11	13	1	04·78 BC
				38·0	44·3	A = 8·3		1	04·78 AB
217	+36·4925	40·0	36 17	...	3±	10	11	1	04·78 BC
					70±	A = 8·7		1	04·78 AB
...	+35·4917	50·1	35 43	243·0	49·6	5·0	8·5	2	04·77
218	...	51·9	64 9	330·5	2·8	11·0	12·0	1	02·73 BC
				296·4	19·1	A = 10		1	02·73 AB (*h* 1833)
219	+35·5001	23 12·8	35 42	309·8	6·1	9·8	10·2	3	04·96
220	+61·2430	15·6	61 45	...	4·0	11·5	12·5	1	04·02 BC
					30±	A = 8·0		1	04·02 AB
221	+35·5153	54·7	36 7	233·9	14·8	8·1	8·8	3	04·87

Notes.

163. Measures discordant.

165. Discordant angles.

168. Discordant angles.

174. 42″ N. 10 sec *p* B.D. + 36°·1528.

175. *h* 5284 is south.

182. According to the list of proper motions in the Harvard section of the Catalogue of the Astron. Gesell., this star has a P.M. in Decl of +0″·103. If B was stationary the distance between the stars would have been 0″·9 at the time of the Harvard observation.

184. Discordant angles.

197. Discordant angles.

202. October 8, A*a* too faint to measure, another still further in the same direction. November 12, glimpsed A*a* and thought it the first of three in a line. November 14, A*a* seen—not sure that there is not a nearer and still fainter one.

204. Discordant distances.

205. Discordant angles.

207. Faint and unsteady poor measures.

212. No particulars, simple entered as double.

213. The fainter star of a wide pair.

219. Discordant angles.

Additional Note.—Since the above paper was presented Professor Hussey's ninth catalogue of new double stars has been received, and No. 195 was found to be identical with Hussey 946 :—

195. 8·0 and 10·0. 240°·8 – 5″·25. 1904·47. Hussey. 2.

On the Determination of Proper Motions without Reference to Meridian Places. By Arthur R. Hinks, M.A.

The purpose of this note is to suggest that the application of photography to the determination of the proper motion of stars leads naturally to an inversion of our ideas in respect of the origin to which these proper motions should be referred. The

on is briefly this, that instead of working backwa
hat we may for the moment call the foreground
, and on the average nearer and faster-moving st
re comprehended in the fundamental catalogues, we m
pplication of photography, work forwards from what
l for the time being the background of most dista
tationary, and on the average fainter stars.
determination of proper motions from meridian obser
volves several difficulties of a systematic kind which m
y enumerated thus.
he systematic corrections from one catalogue to anoth
hen both are referred to the same fundamental syst
systematic reductions from one fundamental system
are well-known troubles which embarrass every inve
proper motion, and need no further comment.
ersonal equation depending on magnitude, which seem
ith the same sign, though to different degrees, all vis
nations of right ascension, becomes troublesome imme
e attempts to determine the proper motions of stars fain
e 9th magnitude, near the limit of visual observatio
introduces into the R.A.'s of all faint stars determin
ography a systematic error depending upon the m
de of the stars adopted as standard. All attempts
ne the value of this visual magnitude equation exp

Kapteyn in his address delivered at the St. Louis Congress,* and also by Messrs. Dyson and Thackeray in their discussion of the proper motion of Groombridge stars (*Monthly Notices*, 1905 March), that the distribution of proper motions is so far from being random that existing determinations of the solar apex are more or less invalidated. But determinations of the solar apex and the precession constant are essentially entangled; if bright stars give a different position of the apex from faint ones, it is more than probable that they will give different values of the precession constant also. At any rate, a first criterion for the choice of stars from which to determine the precession constant is that these motions shall not be systematic over considerable areas of the sky, and it is now certain that the stars which have been actually used do not satisfy that criterion. We can hardly avoid the conclusion that our knowledge of the precession constant is not sure enough to allow us to pass with confidence from the bright stars down the whole range of magnitudes which are within the scope of the photographic method.

Can we then say that our present system of meridian places of bright stars is a sure foundation on which to base the proper motions of faint stars determined by photography? Evidently not; the persistence of magnitude equation in spite of all efforts and the want of homogeneity in the system of the meridian stars forbid it. The former difficulty may be overcome; the latter must prevail so long as star-places are referred to shifting planes of reference whose motion might be adjusted to one homogeneous system of stars observable with meridian circles, but becomes indeterminate if not undefinable when more than one system is involved in the limited number of available stars.

So far as I am aware, the suggestion has not been made hitherto that by the use of photographic methods one may dispense altogether with any reference (except a quite subsidiary one) to these shifting planes, and determine the proper motions of the stars independently of the precession constant. The proposition is evidently true if one admits the possibility of picking out to serve as a background a set of stars so distant that their peculiar proper motions are very small and their parallactic motion infinitesimal. Professor Newcomb gives reasons for believing that the stars extend in every direction beyond a sphere whose radius corresponds to a parallax of $0''\cdot001$. The parallactic motion of stars on that sphere would not exceed $0''\cdot4$ per century (using Campbell's determination of the solar motion). And since the sphere of *lucid* stars probably extends to half that distance, we might hope to get a background not unreasonably faint.

Now it appears to me that the selection of stars for the back-

* This address has not yet been published. The result that there are two distinct streams of stars has been quoted by Professor Turner (*Observatory*, 1905 February, p. 118). By the great kindness of Professor Kapteyn I have had the privilege of reading a portion of the address in manuscript.

becomes a relatively simple matter provided that
aphs are treated in the simplest possible way. Ima
possess for a given epoch a set of photographs o
ntre: exposures, let us say, with an astrographic teles
minute, giving measurable images of stars betwee
m; of three minutes for stars between 8^m and
of thirty minutes for stars between 10^m and
es beyond thirty minutes will not be good for mea
er a large field owing to refractional distortion. S
ose the series continued with an instrument like
lescope down to 15^m; and for a small central field
reflector down even to 17^m. If rectangular coordi
sured on all these plates they can be reduced in
fashion one to another, so that in the end we ha
of rectangular coordinates homogeneous (except for in
causes) for all the stars in the field—a system,
whose orientation and scale-value need not be know
nement, while it may even involve refraction and ab
ovided that the corrections for all these errors, were
pplied, would be expressible as linear functions of
tes.

gine, further, a similar system of rectangular coordin
ame stars on the same centre (with respect to the s

clearly more advantageous to refer everything to an assumed galactic plane.

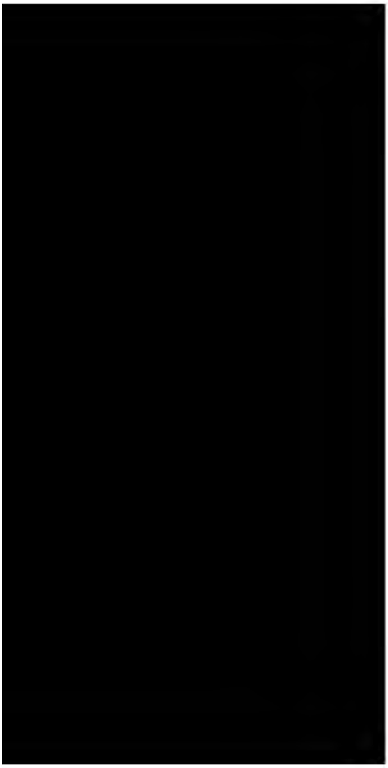
We may anticipate the objection that the method is illusory, since it may be true that there is no motionless background; that there may be no observable stars so far off that their parallactic motion is insensible; and that in any case there can be no certainty about a method that does not tie the various regions together and prove that they are relatively motionless. The objection does not appear to me to be sound, since we determine by the photographic method the proper motions of all the meridian stars which are not too bright, and their places with respect to the rest; so that we have at our disposal the whole results of meridian observation to establish the relative fixity of our different patches of background. Yet this harking back to meridian places is not by any means equivalent to an ultimate return to the method which we proposed to abandon. It is essentially different from it in three respects: we use the meridian observations only to give us the absolute distances apart of stars upon the sphere, which can be obtained practically free from any precessional effects; the proper motions of these stars also, the stars observed on the meridian, are determined, not from the meridian observations, but by the photographic method; and the whole determination of proper motion is carried as far as the final step without any reference whatever to the meridian, so that it cannot get entangled with any of the difficulties that beset meridian observation.

A word may be said as to the choice of regions for the application of this proposed method of taking samples of proper motions. It would be a mistake to start *de novo* with a scheme of centres arranged with perfect symmetry after a cut-and-dried plan, because in so doing we should inevitably miss all the things that are of particular interest. On the contrary, one might let the regions to a great extent select themselves. Some of the most interesting regions of the sky were photographed twenty years ago; we should gain twenty years if those photographs could be measured, and an attempt must be made to do so. And there are a dozen other reasons for selecting particular fields—the presence of a group of Wolf-Rayet stars, or of stellar gaseous nebulæ, or of a star cluster which has already been surveyed. The region round a variable star whose photometric magnitudes are well determined would be interesting; so would a nebula like *Messier* 33, whose condensations are so nearly stellar that some of them might be measured; and one or two binaries whose real orbits may be large enough to measure; and some of the regions containing the fainter helium stars; and the fields of those Novæ which survive as faint stars after passing through the planetary nebular stage. When all these obviously interesting things had been provided for, it would probably be found that their distribution was not as symmetrical as might be desired about the galactic plane; but the gaps could be filled in on

phic *Catalogue* centres. The scheme is in fact
operation, for the astrographic plates have many
asured and published in rectangular coordinates,
some of them is already considerable ; they
nly for stars down to the 11th magnitude. Tl
natter is to discover how good reflector photograp
rrying the measures down to the 15th or 16th
Perhaps I may add that we hope to be able to
tes, and try this at Cambridge in the not distant

idge Observatory :
905 *May* 11.

[redacted]



// MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXV. JUNE 9, 1905. No. 8

W. H. MAW, Esq., PRESIDENT, in the Chair.

Th. Albrecht, Königl. preuss. Geodätisches Institut, Berlin-Potsdam, Germany;
Gustav Müller, Astrophysikalisches Observatorium, Potsdam, Germany; and
Jean Charles Rodolphe Radau, Membre de l'Institut, 12 Rue de Tournon, Paris,

were balloted for and duly elected Associates of the Society.

Major B. F. S. Baden-Powell, 32 Princes Gate, S.W.;
Joseph Henry Elgie, 72 Grange Avenue, Leeds;
Frederick William Longbottom, Haslemere, Queen's Park, Leeds;
Frederick John Marrian Stratton, B.A., Isaac Newton Student in the University of Cambridge, Caius College, Cambridge; and
John Willis, 19 Bouverie Square, Folkestone,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Charles Frederic Aspinwall, B.A., Chestergate, Macclesfield (proposed by E. W. Hobson);
Hubert Hayward Champion, Master at Uppingham School, Rutland (proposed by H. H. Turner);

nt. Alfred Henry Laurence Ferris, R.N.R., Hug
Coleraine Road, Westcombe Park, S.E. (propo
P. Groves-Showell); and
vard MacFarlane, Under Secretary for Lands an
Surveyor for New South Wales, Department of
Sydney, Australia (proposed by T. F. Furber).

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ty-eight presents were announced as having be
since the last meeting, including, amongst others :-

lications of the West Hendon House Observatory,
ed by T. W. Backhouse; 20 charts of the Astro
of the Heavens, presented by the Royal Obser
rich; J. F. Pfaff, Commentatio de ortibus et oc
n apud classicos commemoratis, 1786, presented by

---

the Annual Inequality in the Frequency of M
Disturbance. By William Ellis, F.R.S.

The Moon's observed Latitude, 1847–1901. By P. H. Cowell.

In this paper the coefficient of every term in the Moon's latitude greater than 0″·10 is obtained from the Greenwich meridian observations between 1847 and 1901. The observed motion of the node is reserved until the observations from 1750 to 1851 have been discussed. One of the largest corrections required by the present tables, however, depends upon Hansen's tabular place of the node.

Tables I., II., III. give the scheme of analysis.

Tables IV., V., VI. give the subject matter of the analysis, and Tables VII. and VIII. the results.

The errors analysed are taken directly from the Greenwich volumes and from vol. l. of the *Monthly Notices*. They are in the sense tabular minus observed for ecliptic north-polar distance, or observed minus tabular for latitude. They are subject to two important discontinuities: (i.) of tabular place when Newcomb's corrections were introduced into the the *Nautical Almanac* at the beginning of 1883, the end of my period 117; (ii.) Stone's refractions were used from 1868 to 1877 inclusive.

The following references to previous papers will save much explanation:

Vol. lxiv. p. 421, the numerical values of the arguments are given.

Vol. lxv. December, a similar paper is given for the longitudes.

As an example, I follow through the third line of Table VII. It is there stated that the argument F+D or $2g-g'+2\omega-\omega'$ has a coefficient $-5''\cdot41$ sin in Hansen's tables, and a coefficient $-5''\cdot36$ sin in Brown's theory. In addition to this the reference number 50 is placed against the term, and two other columns are given which must be understood as meaning that when every error is multiplied by $2\sin(\mathrm{F}+\mathrm{D})$ the mean is $+0''\cdot17$, and when every error is multiplied by $2\cos(\mathrm{F}+\mathrm{D})$ the mean is $+0''\cdot40$. In order to understand the details of the arithmetic, the reference number 50 directs the reader to Table I., where it will be seen that the numerical work has been done in two independent ways for this argument, once with the help of an auxiliary angle whose movement in one period of analysis is $400\times26°\cdot311075+12°\cdot156$, or $26°\cdot3414$ in a lunar day; and a second time with the help of an auxiliary angle whose movement is $26°\cdot1818$ in a lunar day. These angles are ${}_{41}\mathrm{A}_3$ and ${}_{55}\mathrm{A}_4$, or angles that go through three and four revolutions in forty-one and fifty-five lunar days respectively. In Table VI. columns 41^s3, 41^c3, 55^s4, 55^c4 give the mean for each period of the errors multiplied by $2\sin{}_{41}\mathrm{A}_3$, $2\cos{}_{41}\mathrm{A}_3$, $2\sin{}_{55}\mathrm{A}_4$, $2\cos{}_{55}\mathrm{A}_4$ respectively. These mean products can be very expeditiously formed owing to the movement of the auxiliary angle in a lunar day being commensurable with 360°. In fact the average time spent

TABLE I.

Scheme of Analysis for Short-period Terms.

Ref. No.	Motion in One Lunar Day.	Excess of Argument over Auxiliary Angle. Middle of Period 44.	Excess of Argument over Auxiliary Angle. Movement in One Period.	Ref. No.	Motion in One Lunar Day.	Excess of Argument over Auxiliary Angle. Middle of Period 44.	Excess of Argument over Auxiliary Angle. Movement in One Period.
		°	°			°	°
1	79·497870	74·92	+ 6·938	22	41·759026	154·45	+ 7·[illegible]
1	79·497870	231·00	+ 34·440	23	41·079120	25·08	+ [illegible]
2	77·688100	102·74	− 59·896	24	40·854141	305·91	+ [illegible]
3	68·124960	301·94	+ 6·740	25	40·738880	359·60	− 6·335
3	68·124960	256·32	+ 80·172	26	39·949256	60·53	− 20·[illegible]
4	67·784720	230·84	− 55·924	26	39·949256	60·53	− 20·[illegible]
4	67·784720	143·77	− 16·545	27	39·833995	114·22	− 66·4[illegible]
5	66·315190	68·08	− 140·591	27	39·833995	114·22	− 66·4[illegible]
5	66·315190	177·74	+ 77·096	28	39·718734	167·91	− [illegible]
6	65·974950	152·26	− 59·000	28	39·718734	262·91	+ 137·[illegible]
7	64·954804	119·39	+ 61·922	29	38·929110	111·30	− 137·[illegible]
7	64·954804	91·79	+ 135·768	29	38·929110	147·74	+ [illegible]
8	64·165180	348·84	− 48·214	30	38·588870	122·26	− [illegible]
8	64·165180	248·27	+ 66·072	30	38·588870	68·05	+ 6·996
9	63·145034	184·37	− 153·753	31	38·024225	192·74	+ 68·048
9	63·145034	246·43	+ 21·944	32	37·908964	246·43	+ 21·944
10	54·602040	320·70	+ 104·966	33	37·799246	113·57	− 21·944
11	54·261800	295·22	− 31·130	33	37·799246	115·49	+ 158·658
12	53·472176	53·63	+ 55·537	34	37·568724	220·95	− 114·152
13	52·792270	85·17	− 59·564	34	37·568724	222·87	+ 66·450
13	52·792270	232·37	+ 43·737	35	37·119340	62·11	− 48·806
14	52·452030	206·89	− 92·359	35	37·119340	17·20	+ 24·206
14	52·452030	2·70	+ 35·359	36	36·888818	308·11	− 13·703
15	52·111790	337·22	− 100·737	36	36·888818	346·07	+ 61·649
15	52·111790	38·51	− 24·848	37	36·779100	175·25	− 57·990
16	51·431884	94·88	+ 1·325	37	36·779100	213·21	+ 17·762
16	51·431884	69·16	+ 1·325	38	36·099194	340·07	− 169·017
17	50·642260	285·50	+ 6·904	38	36·099194	58·59	+ 39·678
17	50·642260	192·74	+ 68·048	39	35·758954	33·11	− 96·418
18	50·302020	167·26	− 68·048	40	29·365970	131·79	− 8·714
18	50·302020	189·82	− 39·192	40	29·365970	346·93	+ 70·712
19	49·622114	211·53	− 13·223	41	29·025730	321·45	− 65·364
20	48·492250	308·55	− 62·560	41	29·025730	253·54	+ 90·298
21	42·548650	46·53	+ 78·282	42	28·236106	21·42	+ 44·442
22	41·759026	19·31	− 127·560	42	28·236106	198·50	+ 73·662

Ref. No.	Motion in One Lunar Day	Excess of Argument over Auxiliary Angle. Middle of Period 44.	Excess of Argument over Auxiliary Angle. Movement in One Period.
43	28·120845	75°·11	− 1°·662
43	28·120845	252·19	+ 27·558
44	27·556200	357·76	− 54·443
44	27·556200	89·46	+ 154·555
45	27·446482	224·90	− 98·330
45	27·446482	316·60	+ 110·668
46	27·331221	278·59	− 144·434
46	27·331221	10·29	+ 64·564
47	27·215960	63·98	+ 18·459
48	26·875720	38·50	− 117·637
48	26·875720	153·47	+ 83·621
49	26·426336	252·52	− 17·702
49	26·426336	326·13	+ 33·949
50	26·311075	19·82	− 12·156
50	26·311075	277·72	+ 51·704
51	26·195814	73·51	− 58·260
51	26·195814	331·41	+ 5·599
52	26·086096	198·55	− 38·288
52	26·086096	49·20	− 0·344
53	25·406190	88·05	− 123·238
53	25·406190	192·74	+ 68·048
54	25·175668	300·12	− 24·161
54	25·175668	131·59	+ 139·233
55	25·065950	167·26	− 68·048
55	25·065950	358·73	+ 95·346
56	24·386044	20·07	− 176·617
56	24·386044	20·48	+ 154·418
57	24·276326	247·62	+ 110·530
58	24·161065	301·31	+ 64·426
59	24·045804	355·00	+ 18·322
60	23·365898	63·40	− 4·291
60	23·365898	167·69	+ 56·037
61	23·256180	290·54	− 48·178
61	23·256180	34·83	+ 12·150
62	22·236034	71·34	− 105·586
62	22·236034	130·12	+ 78·087
63	16·522956	247·31	− 140·818

Ref. No.	Motion in One Lunar Day	Excess of Argument over Auxiliary Angle. Middle of Period 44.	Excess of Argument over Auxiliary Angle. Movement in One Period.
63	16·522956	136°·85	+ 63°·728
64	15·843050	260·71	− 15·722
64	15·843050	298·00	+ 76·351
65	15·502810	235·23	− 151·818
65	15·502810	272·52	− 59·745
66	14·713186	275·83	+ 7·723
67	14·597925	329·52	− 38·381
68	14·372946	250·35	− 128·373
68	14·372946	352·21	+ 138·788
69	14·033280	39·03	+ 2·922
70	13·693040	128·36	+ 43·254
71	13·583322	355·50	− 0·634
71	13·583322	52·98	+ 99·996
72	13·352800	102·88	− 92·842
72	13·352800	160·36	+ 7·787
73	12·788155	192·74	+ 68·048
74	12·672894	246·43	+ 21·944
75	12·563176	113·57	− 21·944
76	12·447915	167·26	− 68·048
77	12·332654	220·95	− 114·152
78	11·883270	126·53	+ 108·147
79	11·543030	101·05	− 27·949
79	11·543030	301·37	+ 117·212
80	10·638145	238·25	+ 19·964
80	10·638145	23·11	+ 81·345
81	10·522884	291·94	− 26·141
81	10·522884	76·80	+ 35·241
82	9·733260	353·55	+ 1·412
82	9·733260	109·74	+ 153·044
83	9·502738	100·93	− 90·797
83	9·502738	217·12	+ 60·835
97	27·161150	97·05	− 3·465
98	13·747850	326·93	+ 21·924
99	13·638230	33·07	− 21·924
100	11·597841	67·98	− 6·025

TABLE II.

heme of Analysis for Terms of Period comparable with One Y

Motion in 40 Lunar Days.		Value at Middle of	
In Degrees.	In Units.	In Degrees.	
160°·80728	4·020182 ÷ 4	316°·68	7
120·00144	1·000012	312·54	2
92·80520	1·031169	333·88	3
88·41648	1 − ·017595	201·02	2
79·19560	2 − ·020110 ÷ 2	308·40	7
65·58600	1·093100	282·92	4
47·61064	1·058014	196·88	4
43·00020	1 − ·044440	250·57	5
38·38976	1 − ·040256	304·26	7
34·00104	1·038921	171·40	5

TABLE III.

heme of Analysis for Terms of Period comparable with Ten Yea

Motion in 200 Lunar Days.		Value at Middle of
In Degrees.	In Units.	In Degrees.

TABLE IV.

r, in Tenths of a Second of Arc, of Moon's Latitude (Observed minus Tabular) for each Column of Forty Lunar Days.

1	2	3	4	5	6	7	8	9	10
2	+ 5	+ 9	+ 12	+ 12	+ 16	+ 2	− 3	− 2	+ 10
3	+ 14	+ 22	+ 4	+ 12	− 1	− 7	− 3	+ 3	+ 5
5	+ 17	+ 18	+ 15	+ 13	+ 11	0	0	− 2	+ 12
8	+ 5	− 9	+ 4	+ 10	− 4	+ 3	+ 2	+ 2	− 1
1	− 3	− 7	− 6	− 2	+ 7	+ 5	− 16	+ 2	+ 5
5	− 5	− 1	− 1	+ 7	+ 8	− 6	+ 6	− 1	+ 3
2	+ 7	+ 1	+ 7	− 2	− 2	− 5	+ 2	− 2	+ 3
1	+ 5	− 10	+ 9	0	+ 3	+ 5	− 7	− 3	+ 3
5	+ 4	+ 3	− 5	0	+ 2	+ 3	− 2	+ 2	− 10
0	− 3	− 1	+ 2	− 5	− 6	+ 6	− 6	0	+ 2
1	− 9	− 9	− 3	− 6	+ 3	+ 7	0	− 10	+ 3
12	− 3	− 4	+ 3	− 4	+ 10	− 10	+ 5	+ 2	− 7
7	− 3	+ 1	+ 6	+ 2	+ 4	+ 19	+ 3	0	+ 7
3	+ 10	− 1	− 2	+ 1	− 2	− 6	− 7	0	+ 1
5	+ 1	0	0	− 7	− 7	− 6	+ 1	0	− 1
0	− 3	− 1	− 5	− 8	− 2	− 5	+ 2	− 10	− 1
8	− 3	− 9	+ 1	− 9	0	− 3	+ 6	0	− 3
3	+ 4	+ 3	+ 5	+ 2	0	− 2	+ 4	0	+ 11
4	0	+ 7	+ 11	+ 9	− 2	+ 4	+ 15	+ 14	+ 10
13	+ 13	+ 16	+ 7	− 4	+ 12	+ 22	+ 7	+ 10	+ 15
9	+ 10	+ 9	+ 3	+ 6	+ 15	+ 12	+ 11	+ 7	+ 8
5	+ 14	+ 10	+ 13	+ 11	+ 17	+ 10	+ 2	+ 7	+ 8
7	+ 9	+ 17	+ 14	+ 18	+ 1	+ 10	+ 2	+ 4	− 5
6	+ 24	+ 30	+ 5	+ 7	+ 2	+ 1	+ 1	+ 14	+ 11
26	+ 20	+ 2	+ 22	− 7	0	− 5	+ 7	+ 7	+ 12
18	+ 11	+ 4	+ 5	− 8	+ 1	+ 1	+ 23	+ 19	+ 10
12	+ 13	+ 13	+ 6	+ 14	+ 24	+ 23	+ 11	+ 22	+ 4
7	+ 4	+ 3	+ 4	+ 10	+ 19	+ 12	− 7	+ 10	− 3
4	+ 3	[+ 20]	+ 19	+ 19	+ 6	− 6	− 7	− 11	+ 7
9	+ 7	+ 13	+ 19	7	− 2	− 27	+ 3	+ 3	+ 10
12	+ 2	16	− 11	− 20	− 27	− 3	+ 12	+ 1	− 6
12	− 16	− 22	− 16	− 3	+ 5	+ 8	− 6	+ 4	− 11
3	− 10	− 4	− 8	− 2	− 13	+ 7	− 9	− 8	− 14
3	− 14	− 1	− 8	− 11	− 4	− 4	+ 2	0	− 5
0	− 2	− 4	− 10	+ 6	− 11	− 5	+ 2	+ 1	0
7	− 5	− 4	− 5	− 8	− 9	− 6	− 1	+ 5	+ 2
6	− 13	− 2	− 16	− 2	− 18	− 10	− 2	0	− 8
3	− 11	− 5	− 3	− 8	− 4	+ 3	− 1	+ 10	+ 2
4	− 9	− 3	− 9	− 7	− 10	− 7	+ 1	− 7	+ 7
0	− 4	+ 3	[0]	− 14	− 2	− 2	− 7	+ 10	+ 12
1	− 3	− 3	− 1	− 10	− 8	0	− 2	− 2	+ 5
0	− 11	− 12	− 14	− 2	− 8	− 3	+ 1	− 10	+ 6
4	+ 1	− 14	− 7	+ 1	+ 2	− 3	− 8	− 9	0
0	+ 4	+ 6	+ 8	− 1	0	− 4	− 11	+ 3	+ 5
9	+ 11	+ 14	+ 10	− 8	− 3	− 10	0	+ 12	+ 6
0	+ 2	+ 1	− 3	− 3	− 5	+ 4	− 4	+ 8	− 3
1	− 5	− 1	− 3	+ 1	− 9	+ 8	+ 4	− 4	− 12
2	− 5	− 1	− 1	+ 6	− 4	+ 2	− 6	− 3	− 8

TABLE V.

Error, in Fiftieths of a Second of Arc, of Moon's Latitude (Ob minus Tabular) for each Half-period of 200 Lunar Days.

A.	B.	C.	D.	E.
+40	+ 7	−28	+63	−27
+23	− 5	0	+21	−37
+55	− 7	+17	+30	−37
− 3	− 4	+13	+54	−11
+58	−28	+31	+58	0
+21	+ 3	+41	+84	−13
+18	−20	+45	+28	−29
+ 2	0	+66	+31	− 9
−17	− 1	+37	+65	−39
+ 3	+33	+53	−11	−38
− 5	+11	+53	+41	−30
+10	−14	+44	−13	+10
+11	− 1	+65	−33	−32
− 4	−13	+12	−23	−16
+ 5	−17	+72	−79	−15

TABLE VI.

Value, in Tenths of a Second of Arc, for each Period of Analysis of Errors of Moon's Latitude (Observed minus Tabular), each multiplied by certain Factors.

77°17.	77°17.	68°15.	68°15.	37°8.	37°8.	37°7.	37°7.	53°10.	53°10.	69°13.	69°13.
+1	+2	+1	−2	−4	+2	−1	+1	+1	−1	0	+1
−4	+6	+6	+3	−1	−1	0	−1	−1	+1	0	−1
−3	−1	−2	+2	0	+2	+4	−2	+1	−3	−2	+1
+2	−1	+1	−3	+2	+1	0	−1	+1	−1	−1	0
+2	−2	+2	−3	−1	+1	+1	−1	+2	+1	+2	−1
0	−1	+1	−1	0	−2	−3	+1	+3	−1	+2	−2
−1	+4	−3	+3	+1	−3	−1	−2	−2	+2	−2	+2
+1	−1	+2	+1	+2	+2	0	+5	+2	+3	−2	+3
+5	+1	−1	+5	−2	+5	+2	+2	0	+1	0	0
−2	0	+1	−1	+1	+1	+2	−1	0	+1	0	0
+3	−1	−1	+1	+1	+1	−1	−5	+2	+5	−3	−4
−1	+1	+1	−1	0	−1	−1	+1	0	+1	+1	0
+2	−1	−2	0	−4	−2	+3	0	0	−1	+1	0
−1	−1	0	+1	+4	−1	+3	−1	+2	0	−1	−1
+1	−2	−3	0	0	0	−2	+4	−4	−4	−7	−1
0	−1	−2	0	−1	−1	−1	−2	0	+2	−1	+2
+2	0	0	−1	−1	−5	−3	+1	+1	+1	+1	0
−2	−2	−3	0	+5	+3	−3	+1	0	+2	−1	+1
+2	+1	+2	+1	+2	0	−5	−1	−2	−3	+3	0
−5	0	−5	−2	−4	+1	−2	−5	+6	0	−5	+3
−4	+3	−4	−2	+2	−2	+1	+1	0	−2	−2	+1
−5	+3	−3	−5	+1	−2	−6	+1	0	+5	+5	−1
+3	−6	+4	+5	−2	−2	−2	+3	0	+3	+3	−1
+6	−4	−2	+6	+4	+2	−6	0	−2	−4	−3	−3
+3	−1	−3	+1	+1	−3	0	+2	−3	+1	−3	+2
+2	+1	−1	−2	+1	+1	+1	0	−2	−1	−1	−2
−3	+3	+4	0	−6	−1	−1	+6	+5	−1	+3	+4
+1	−3	−4	−1	+3	−1	−3	−1	−3	0	+1	−2
−1	−5	−4	−1	−5	−2	−9	+1	−5	−7	+6	+3
+3	+1	+2	−2	0	+1	−1	0	0	−1	0	+1
0	+1	0	0	0	+1	+1	0	−1	0	0	−1
+1	−2	+1	−2	+1	−4	−3	−1	−1	+5	+6	0
+5	−1	+4	+1	−2	−2	−3	0	−2	+1	−1	+2
+2	+1	0	+2	+2	−1	+1	0	−1	+1	−1	+3
0	+1	−1	0	+2	0	−2	+2	−1	−3	+1	−3
−2	+1	−1	−2	−1	−6	+1	+1	−1	−1	0	−1
0	+4	−2	−3	+3	+2	−1	+2	+2	0	−1	+3
0	+2	0	−2	−6	+2	+1	−1	+2	+1	−3	0
+4	0	−4	−2	+1	0	−1	+1	−1	0	+1	−1
+1	+4	+3	−3	+3	+3	−2	−2	+2	0	−1	−2
+2	+1	0	−3	−1	−1	−2	+1	+2	+1	+2	−2
−2	+1	+1	+2	+4	+1	−1	0	−1	+1	0	+1
−2	−1	−3	+2	+1	0	−1	0	−2	+1	−1	+2
+1	−2	+1	−2	+2	−1	+1	−3	+4	−1	+5	0
+1	0	0	0	+1	0	+4	−1	−3	+2	−2	−3
−1	0	−1	0	+3	−1	+1	−1	0	0	0	0
−2	−2	0	−3	0	0	−1	+1	+1	+1	−1	0
0	0	0	0	0	−3	0	−1	+1	−2	−1	+2

Period.	27°5.	27°5.	49°9.	49°9.	50°9.	50°9.	39°7.	39°7.	28°5.	28°5.	4
86	+3	+5	−1	−7	+2	−2	−3	+2	+1	−1	
87	+4	+5	−3	+1	−3	+1	+3	+3	+2	−3	+
88	+1	0	+3	−2	−4	0	−7	+2	−7	−6	−
89	+5	−1	−2	+4	+5	−4	+6	+2	−5	−1	−
90	−1	−3	+2	−4	+3	+3	−3	+1	0	0	+
91	−5	−2	+3	+3	−3	−1	+3	+3	−3	+2	+
92	+3	0	−1	+3	−3	0	−1	+2	+2	+1	+
93	+3	+3	+4	+3	+3	0	+3	−1	+3	−2	+
94	−3	−3	−3	+1	−3	+2	−1	−2	0	+2	+
95	0	+2	−4	+1	0	0	0	+1	+2	−1	+
96	−2	+1	+2	+1	+1	+1	+1	−1	+1	0	
97	+2	+2	0	0	+1	0	0	−2	+2	+1	−
98	+1	−2	0	+4	+4	+3	+2	+4	+2	+4	+
99	−2	+2	+1	+1	+2	−1	+2	+2	0	+3	
100	0	0	1	+1	+1	+1	−1	0	0	0	−
101	+2	0	+1	−2	+1	+2	+1	−2	0	−1	
102	−2	−3	0	0	−1	+2	0	+1	0	−2	+
103	+4	−2	0	−3	−1	0	−2	0	+1	+2	
104	0	−1	+1	−2	−1	0	0	0	+1	+2	+
105	−5	+1	−1	0	−3	+5	+1	−5	+1	+2	−
106	−5	−1	0	+2	−3	−1	0	+3	0	+2	+
107	−1	0	+2	+7	−1	+4	+3	+3	0	+2	+
108	0	+6	+1	+3	+1	−4	0	−3	+3	−1	+
109	0	−4	0	−3	−1	−5	+4	−2	−2	0	+
110	+3	0	+2	+2	−2	−1	+2	−1	+1	0	−
111	−1	+2	+1	0	−2	+1	+2	+3	−1	−4	−
112	−2	−1	0	+1	+2	−5	+1	−5	+1	−6	+
113	−1	+5	+3	+3	+2	−1	+4	0	−2	+5	+
114	+1	0	+1	0	0	−3	+4	−2	−1	−1	+
115	+5	+2	0	+4	+1	−4	0	+3	−2	+4	−
116	−1	+3	+5	+3	−8	−3	−2	+10	−3	−10	−
117	+2	−1	+2	−2	0	+1	+2	+1	0	−4	−
118	−5	−1	−2	−1	−2	+1	−3	+1	−2	−1	+
119	0	+4	0	+1	0	+4	−4	−2	+4	+1	−
120	−3	+1	+1	−2	+1	+1	−2	−1	−2	+2	+
121	−2	+2	+1	+1	+3	0	−1	−3	+3	0	+
122	−2	−2	+1	+1	−2	+2	−2	+3	+3	+1	−
123	+2	−2	+2	−1	−1	−2	+1	−1	+2	0	+
124	+4	+2	+2	−4	+2	+1	−3	0	+3	−3	+
125	−3	+1	0	0	0	0	−1	+1	+2	+1	−
126	−1	0	+1	0	−2	−1	−1	+2	−1	+3	+
127	−2	+1	+1	+2	−1	−1	−2	−1	+3	0	+
128	+2	0	+1	+2	−2	+1	−1	−2	−1	−2	+
129	+1	+3	+2	+1	−5	0	+2	−4	+2	−1	−
130	−1	−1	+3	+1	0	+2	−1	−2	+1	+2	−
131	+2	+2	0	−1	+1	+1	+1	0	+2	−1	
132	0	+2	−3	−1	−2	+2	−1	+3	−3	−1	+
133	+1	+2	0	+2	0	−1	0	0	0	−1	−

68°12.	68°12.	sin 5D.	cos 5D.	53°8.	53°8.	27°4.	27°4.	68°10.	68°10.	41°6.	41°6.
+5	+3	+1	−6	+1	−7	+2	+1	0	+2	−2	−1
−2	+4	−3	0	+1	−2	+5	−2	0	−3	−2	+1
−3	+3	0	+3	0	−4	+6	−3	+2	+2	+1	0
+1	−5	+2	−4	−1	+2	+4	+2	−4	−2	+1	−5
+3	+2	−1	−3	0	−5	0	−2	+1	−3	−3	+2
0	−1	+3	0	−2	+2	0	−2	0	+2	+1	+3
+2	0	−1	−1	−1	+1	+1	+2	0	0	0	−1
0	+1	0	+1	−1	0	−1	0	0	−1	0	+1
+2	+2	+1	−3	+1	−1	−1	0	−2	−3	−4	+2
−4	+3	−2	0	+2	+2	−1	−4	+3	−1	+2	0
+4	−6	−4	+6	+1	+2	+3	+1	+1	−5	+3	+2
+2	−1	+2	−2	0	+3	+1	+4	0	0	−1	+2
+1	+1	−2	+2	0	+2	0	+1	0	+1	+1	−1
−3	0	−2	+2	0	−5	−3	−4	−5	−3	0	−3
0	−1	0	+1	−1	−3	−1	+3	−1	−2	+1	+2
0	−1	+2	−1	−1	−3	+1	−1	−1	−2	−2	+2
+2	−1	−2	+3	+4	−2	+4	+4	−3	+2	−1	0
−2	−2	−1	−1	+1	−2	−2	+1	+2	+2	−2	+1
+1	+3	−1	0	−1	+1	−2	2	0	−2	0	+2
−3	0	−3	−1	+3	+1	0	−6	+1	+2	+2	−2
+6	+5	−4	−2	−4	−1	+1	−2	+1	−3	+4	−1
0	+3	+1	+4	+3	0	−2	−2	−1	0	+3	+1
+3	+1	−3	+2	+2	+1	−1	−2	−1	+1	+4	+2
−4	+1	−3	+3	+1	−5	−5	−1	+7	+1	+5	+6
−2	−1	+2	0	−2	−2	+1	−1	+2	−2	0	+5
+1	+2	+2	−2	+1	−1	+5	+3	+1	+6	+1	−5
−6	0	+1	−5	0	0	−1	+2	−1	+1	−1	+2
+1	0	0	+1	−3	+2	+2	−3	+2	−4	+4	0
−7	+4	0	−4	−2	−1	−1	−1	−1	+2	+1	−2
0	−4	−1	−5	−1	0	−2	+4	−3	+2	0	+3
−2	−6	+5	−2	+3	0	0	−2	+7	+4	+6	+9
0	0	+2	−2	−4	+2	−3	+4	+2	+4	−2	0
−1	+1	−2	−1	−2	−1	−2	−2	+2	−3	−2	−1
0	+1	+1	−1	−1	+1	+3	0	+2	−4	−2	−4
−3	−4	+1	−2	0	−1	+1	+1	−2	−1	+2	−3
0	+4	+4	0	+1	+3	0	+4	+3	−4	−2	+3
−2	+1	0	−2	+1	+3	−1	−1	0	+1	+2	−1
+3	−3	−2	−3	+2	−2	+2	−2	+2	+2	+3	+3
0	0	−2	+1	0	+3	−3	+4	+1	+2	0	0
0	−1	+1	0	−3	+1	+2	+1	0	−1	−3	−1
+1	0	0	+2	+1	+2	+1	−1	0	−1	+2	0
0	0	0	0	−1	−2	−1	−5	+3	+1	−2	+1
+7	−2	+3	+3	+3	−3	+3	+1	0	−3	−2	+2
−2	−2	−2	+1	+5	−2	0	+2	+1	+4	+3	0
−1	+3	−4	+1	+2	−1	+1	−1	−4	+3	−6	0
0	+1	0	−2	+2	−1	+3	−3	+1	−1	−1	0
+2	+1	0	+2	0	−1	0	−2	−1	+1	+1	+2
+1	0	0	+1	−2	0	0	+2	+1	+1	+1	0

97	−2	−1	+2
98	−4	+1	+5
99	−1	+1	+2
100	−2	0	−2
101	+4	0	+2
102	+2	−1	−1
103	0	−3	−1
104	+2	−1	0
105	+2	−2	0
106	−2	+4	−4
107	+3	−4	−1
108	+2	+5	+2
109	−2	−6	−4
110	+4	+1	+3
111	+3	−2	+2
112	+2	−1	−2
113	+1	−3	−3
114	+2	−2	+1
115	+2	−1	+1
116	+7	+10	−11
117	+1	0	0
118	−2	+2	0
119	−2	−4	−4
120	−1	+3	−2
121	+1	+1	0
122	+3	0	−2
123	−6	0	−2
124	−1	0	−2
125	0	−5	+5
126	−3	−1	+3

50°7.	50°7.	29°4.	29°4.	37°5.	37°5.	68°8.	68°8.	77°9.	77°9.	69°8.	69°8.
+2	+2	−3	0	+3	−5	+7	−4	+6	−2	+4	+6
−2	+4	+5	0	−1	−5	0	+2	−4	−1	+4	+3
+2	−3	−1	−5	+4	+3	+1	−2	−1	+1	−2	0
0	−1	−1	−6	−1	+1	+2	+2	+3	+1	−2	+1
−2	0	−1	+2	−4	+2	+1	+3	−4	+2	+6	+2
−2	0	−1	0	0	0	0	−2	−1	+3	0	+1
−3	−1	+1	+2	−1	+3	0	+3	+1	+3	−1	−2
+1	−3	+1	+2	0	+1	0	−3	+2	+1	+3	0
−1	−1	−1	0	+1	0	0	+5	+2	−4	+1	+2
+2	−1	−1	+2	+2	+6	−1	−1	−3	−3	0	+5
0	+3	−1	−2	+1	−1	−1	−1	0	−1	−2	+1
+2	+4	+2	0	+1	−3	−4	+2	−1	−2	0	−4
−3	0	−1	−1	−2	−1	0	−1	0	+1	+1	−2
0	+2	−5	−4	−3	0	+2	0	+5	0	+5	0
−1	0	−1	0	+3	0	−1	+3	−2	−3	+2	+1
0	+1	0	0	−1	+2	−1	−1	+1	+1	+2	−2
−2	0	+1	−1	−3	−1	−1	0	−1	+1	0	−1
−1	0	−1	+3	+1	0	+2	0	0	+4	+3	−2
−2	+3	+1	+3	+1	−2	−2	0	+1	0	+2	+1
+2	−4	−1	+3	+2	0	−3	+2	+4	+5	−5	+4
−1	+3	+1	−4	+1	+1	+3	−1	+2	0	−2	−1
+1	+1	+2	+1	−1	−2	+2	+3	−3	−3	−1	0
+1	−1	+1	+4	+1	0	−2	−1	−3	+1	+2	0
−3	−4	0	+1	−3	−2	+5	−1	+4	−1	−2	−4
0	−1	+5	0	+3	+6	+2	−4	+1	+3	0	+1
+3	−3	+3	−1	+3	−1	−4	−2	0	+5	+2	−3
+6	−6	+1	0	+3	−2	+4	0	+8	+1	+9	−2
−2	−3	0	+1	+3	0	−4	+1	+3	−2	−2	+3
0	−5	−4	+5	0	+8	+6	0	−4	−5	−3	+3
0	+3	0	−2	−3	−4	−1	0	−2	0	−1	−2
0	+2	−1	0	0	+3	+2	0	+1	+1	−1	−1
−3	0	−3	0	+3	+1	+1	−2	0	+2	+1	0
−3	−1	+4	+1	+1	+2	+1	−4	−3	−2	+1	−2
−1	−1	+1	0	−3	+2	0	−4	+2	−4	−4	+4
−1	−2	−2	+2	0	+1	+2	+1	−6	0	−6	+1
+2	−3	−1	0	−1	0	−1	−3	−5	+1	+2	−3
+4	0	0	−1	0	−2	−1	+2	−2	+4	+4	0
+1	+2	+1	+1	−2	+4	0	0	0	+2	−3	0
−2	−1	+5	−2	−1	−1	+1	+2	+2	−1	−1	0
−1	+3	−5	+3	+5	0	0	+1	−1	+1	0	+1
+2	0	+2	−1	−1	+1	−2	−3	+3	−1	+1	+2
−2	+1	+4	0	−1	0	+1	+2	−1	−2	+2	+2
−1	+1	0	−1	+1	+3	−4	−5	−6	−3	−3	−2
+1	−2	+1	−3	+1	+1	+2	+1	−2	+4	−2	−4
+2	0	+2	−1	+1	−1	−1	+1	+2	0	0	−1
0	+2	−1	+2	−1	−1	+3	−2	+1	−3	+2	+1
+1	0	+4	−1	+1	−2	+1	+2	−1	+2	+1	0
0	0	0	−1	+1	+2	0	0	−1	0	−1	+1

Period.	53°6.	53°6.	27°3.	27°3.	45°5.	45°5.	64°7.	64°7.	55°6.	55°6.	37°6.
86	+5	0	−1	+4	−1	+4	−2	−5	−2	+4	−1
87	0	−1	0	+2	0	+2	−4	+1	0	+4	0
88	−2	−1	0	−2	0	−2	−6	−3	−6	+1	+3
89	−2	+1	+4	−2	+4	−2	−4	+5	−4	+4	+2
90	+2	−4	−3	0	−3	0	0	−4	+2	−3	+2
91	+4	−4	0	+2	0	+2	+3	+3	−2	+3	+2
92	−2	+4	0	+2	0	+2	+3	+2	−3	+1	−1
93	−3	+1	+3	−1	+3	−1	+1	0	−1	+2	−3
94	−2	−6	+2	−2	+2	−2	+2	0	−1	−1	−1
95	+2	−4	+3	−2	+3	−2	−2	−1	−1	+1	0
96	+3	−3	−4	−2	−4	−2	+3	−1	+1	−2	0
97	0	+4	−5	+2	−5	+2	0	0	0	−1	−2
98	0	+3	−5	+2	−5	+2	0	+1	−1	−1	+4
99	−3	+2	−3	−1	−3	−1	+1	+1	−1	+1	−1
100	−1	+2	−5	0	−5	0	0	−4	+4	0	+1
101	−1	−1	−1	+2	−1	+2	+1	+2	−4	−2	+2
102	+4	−4	+3	0	+3	0	+1	0	−1	0	−2
103	+2	0	+3	−4	+4	−4	+2	−1	−2	0	0
104	−1	+2	+2	−3	+2	−3	+2	−1	−1	−2	−3
105	−5	+10	−2	0	−2	0	+3	+1	+1	−2	−2
106	−4	+3	−1	0	−1	0	+2	−3	+1	−3	−4
107	−2	−2	−2	−1	−2	−1	+2	−2	+3	−1	+2
108	+2	+3	0	−3	0	−3	−5	−4	+1	−6	+4
109	+2	+2	+3	+4	+3	+4	−1	+2	−2	−1	+2
110	−3	+1	+3	+6	+3	+6	+2	−3	+1	+5	−1
111	−2	+2	0	+1	0	+1	0	+6	+3	−8	0
112	−5	+2	+1	−7	+1	−7	+3	−2	−4	0	+1
113	+1	+1	−2	+1	−2	+1	−1	+2	+3	0	+1
114	0	−1	+1	−8	+1	−8	0	−7	−6	−4	−2
115	−3	−2	−1	−6	−1	−6	−2	+1	−2	+1	−1
116	−4	−4	−13	+2	−13	+2	−2	−9	+1	−8	+4
117	−4	+1	+2	+1	+2	+1	−2	−1	0	−2	−2
118	−3	−1	+3	+6	+3	+6	+5	−2	0	+4	−1
119	+3	−4	+1	+2	+1	+2	0	−1	0	+2	+2
120	+3	−3	+1	0	+1	0	0	+1	0	−1	0
121	+1	+3	+4	0	+4	0	−2	−1	0	+2	−1
122	−7	+1	+2	−2	+2	−2	−2	+3	+2	+2	0
123	−3	−5	+1	−2	+1	−2	+2	−3	−2	−4	−2
124	+5	+3	+2	0	+2	0	+2	+1	+2	+2	+2
125	+3	+1	0	−1	0	−1	−1	+2	−2	+1	0
126	−3	+4	−3	+1	−3	+1	−4	+2	−3	−3	0
127	−2	+4	+2	−1	+2	−1	0	−3	+3	+1	−1
128	−4	−1	+3	+1	+3	+1	0	−2	0	+2	0
129	+2	−3	+4	−1	+4	0	−1	+2	+1	−1	+1
130	+4	+1	+7	−2	+7	−2	+5	−4	−5	−1	−2
131	+1	+4	−1	−5	−1	−5	−1	+1	+1	+1	+1
132	−1	+2	−1	−4	−1	−4	+1	−1	0	−1	0
133	0	+1	−4	+1	−4	+1	−1	+1	−1	+2	+1

28°3.	sin 3D.	cos 3D.	77°8.	77°8.	29°3.	29°3.	68°7.	68°7.	39°4.	39°4.
+1	−2	+5	−1	+3	−1	−1	−1	0	−1	+2
+1	+3	+1	0	0	−1	−1	+1	+3	+1	+3
+1	+6	+1	+1	+6	+5	−1	+3	−3	+3	+2
+1	−1	−3	+1	+5	+3	+2	+2	+2	−3	0
−1	0	−1	+3	−1	+5	+1	+1	+5	−2	−5
+2	+1	−1	−2	+2	−2	−1	+3	0	−2	−2
+4	+5	0	0	+1	0	0	−1	−1	−1	+1
+3	−1	0	+1	−3	−2	+3	+2	+3	+4	+1
0	−3	+2	−2	+1	+1	+1	+1	+1	+1	+1
+1	−1	+1	+2	−1	+2	−1	+1	+1	0	+1
−2	0	−1	+3	+1	+1	+3	−3	−3	+4	0
−3	−4	+2	+1	+4	−5	−1	+4	+5	−4	−5
−4	−3	−3	−1	−3	+1	+1	0	−1	−1	+1
+2	+2	0	+2	−2	−3	−1	−3	−2	−3	+2
−2	+1	+2	0	+2	+1	+1	0	0	−1	0
+1	−1	+3	+2	−3	+1	−3	0	+3	−2	+2
−2	0	+2	0	+3	−3	+1	+1	0	0	0
0	+2	+2	+1	−2	+1	+2	+2	−1	−1	+2
−2	+2	+2	+1	0	−1	0	−2	0	+2	+1
−2	−3	+4	+7	0	+1	−6	+4	+2	+3	0
+5	+2	0	+3	−1	+2	−2	−2	+2	0	+2
0	−2	0	+3	+1	+2	+2	0	−3	0	−2
+4	+1	−4	0	+2	−2	−1	−2	0	−1	−2
+3	0	−6	−3	0	+1	+1	−2	+2	−1	−4
−4	−2	−1	−4	−1	+3	+4	−4	+3	+2	−4
0	0	+4	−1	0	+1	+2	−2	−2	+1	+3
+3	0	−5	+8	0	+8	0	−2	−7	−7	0
−2	+1	−2	−3	+1	−3	−2	−4	+1	−3	+2
+4	−1	0	0	+2	−3	−1	−5	+4	−1	−6
0	+4	+4	+1	−6	−1	+5	−3	−3	+3	−2
−3	+2	+2	+5	+5	+2	−7	0	+7	−5	−3
0	−3	0	+2	+1	+1	0	−1	−1	0	0
+1	+5	−2	0	+1	−1	0	−2	0	0	+1
−3	−1	−1	0	0	+1	0	+1	0	0	−1
0	−1	0	−1	−1	+1	+1	0	0	0	0
0	+2	+5	+3	−4	−5	+1	+4	0	+2	+3
+5	+3	+1	−1	+2	+1	+1	0	0	0	0
−3	+1	+3	−2	+4	0	+6	+5	+5	−7	−2
−3	0	−2	−1	0	−1	−1	+1	−1	−2	0
−1	+4	+1	+2	−4	+3	+3	−3	+1	0	+2
−1	+1	−3	+1	+1	−1	0	+2	0	+1	−1
+2	+4	−1	0	−6	−6	+2	+3	+5	+1	+5
+1	+2	−2	−3	0	−3	+3	−2	+4	−4	−1
0	−1	+1	+1	−1	+1	0	0	0	0	−1
+2	+4	−3	+1	−1	0	0	0	−1	−1	+1
+3	+1	−1	0	0	−1	0	+1	0	−1	−1
0	0	0	+1	+1	0	−1	−1	0	−1	0
+1	0	+1	0	0	0	0	+1	0	+1	0

Period.	49°·5.	49°·5.	69°·7.	69°·7.	50°·5.	50°·5.	49°·4.	49°·4.	37°·3.	37°·3.	50°·4.
86	+1	+5	−7	+1	+6	+2	+3	−5	−1	−6	+3
87	−1	+5	−2	−5	−2	−6	−1	−2	−1	−3	+1
88	−4	0	−1	+3	−5	+4	−2	−10	+9	+3	+1
89	+2	+2	+3	+3	−3	+1	+2	+4	−1	−3	+1
90	−5	+2	−4	−3	−2	0	0	−2	−3	+2	+5
91	−2	−1	+2	0	0	0	−1	0	−1	+1	−3
92	−2	−1	0	+2	−1	+1	−2	−2	+1	−2	−1
93	−3	+2	−1	+3	+2	−1	+2	−2	−1	+3	−1
94	+1	−1	+1	0	−2	−1	−1	+3	0	−1	+6
95	0	0	+1	−1	−3	−2	+2	+1	+2	0	+2
96	+4	0	−2	−2	−1	+1	+5	−5	+5	−4	+3
97	+3	−5	−4	−3	−1	+2	−1	−1	+2	−1	−5
98	0	−1	+1	0	+1	−4	−1	−2	−1	+2	−3
99	+4	0	0	+4	+2	+4	+1	0	−1	−1	+4
100	−1	0	+2	−1	−2	−1	−1	−3	−3	−1	−3
101	−2	0	−1	+1	−1	−4	+2	−1	+1	+2	−1
102	0	+1	+1	+1	0	0	−1	0	+2	0	+2
103	0	−2	+2	0	+1	−1	−1	−2	0	+3	−3
104	0	−2	−1	+1	−2	−1	−1	−1	−3	+1	0
105	+1	−4	−4	−3	0	0	−3	−2	−3	−4	0
106	−1	+1	−2	0	+1	0	0	+1	−2	+1	+4
107	+1	0	0	−1	−3	+1	+1	+1	−1	+1	−2
108	−1	+1	+2	−1	−1	+2	−1	−3	−2	−1	−1
109	−6	+2	+4	+6	+2	0	−1	−2	−3	0	−2
110	−2	−4	−6	+1	+2	−4	+4	−2	+4	0	+3
111	−1	+1	0	0	+4	0	−2	+1	−1	−1	+1
112	+4	−3	−3	+3	+2	+2	+2	0	−3	−2	+1
113	+3	0	−2	−1	−1	−1	0	−4	−2	−1	+2
114	−8	+1	−5	+7	+4	+4	+2	−5	+3	−3	+2
115	+3	−1	+1	+2	0	−4	−1	−2	+2	0	−1
116	−1	−6	+5	+1	−1	−4	+5	+6	−6	−4	−6
117	0	−1	−1	+1	0	−2	+3	−3	−4	+1	−2
118	+1	−1	0	0	−1	+3	−1	+1	−1	+1	−2
119	−2	0	−2	+1	+4	−1	−4	−3	0	−4	+3
120	+1	−1	+1	+2	−2	+2	0	+4	−4	−2	+1
121	−3	+2	+2	−1	+1	0	−1	−2	+1	+2	−1
122	+2	+1	+1	−2	−1	+2	−1	+1	+1	+2	0
123	+3	+5	+2	+3	−1	−1	+4	+3	+4	+3	+4
124	−2	+1	−1	−3	−1	+3	+4	−1	+1	+4	−2
125	−1	0	+2	+2	−2	+3	−1	−3	0	+2	−3
126	+2	+1	0	−2	0	0	−1	0	0	0	+3
127	−2	−4	−2	−1	−3	−2	+2	−5	−2	−7	−6
128	−1	+4	−3	0	−1	−1	+1	−2	+2	−1	+1
129	0	−1	+1	+1	+1	+2	+1	−2	+1	+3	0
130	−1	+1	+1	0	0	−1	−2	+1	+2	0	0
131	+2	0	+2	−1	−2	−2	+1	+2	+2	0	0
132	+1	+1	−1	+2	−1	−1	+3	+1	+2	+1	+1
133	0	−1	+1	0	−1	0	0	+1	−1	+1	−2

ʼ5.	64°5.	77°6.	77°6.	39°3.	39°3.	53°4.	53°4.	27°2.	27°2.	68°5.	68°5.
4	+5	+6	+1	+4	+1	−3	0	+1	−4	−6	+2
1	0	−1	0	0	+1	−1	−1	−1	+1	−2	+2
3	0	+2	+1	−2	−4	−5	+2	+2	−2	+5	0
3	−3	+4	+1	−2	+2	−1	0	+1	−3	+2	+1
3	0	+1	+2	−1	−6	−4	−4	−1	+2	0	−3
4	+2	−2	+3	0	+4	−5	−5	+3	+2	−1	−2
2	−3	+4	+1	−4	−4	−2	−3	−6	−2	−8	0
1	+1	−1	−1	+1	0	−2	−2	0	+3	−2	+3
5	+2	−4	−2	0	−4	+3	−1	−1	−3	+3	+3
1	+1	0	−2	−1	+2	+3	+3	0	+1	+3	0
1	0	+1	0	+1	−3	+1	+5	0	−2	−1	−3
3	−6	−4	−4	−2	+3	−9	−1	−8	+4	−7	+2
1	0	+1	0	+3	+3	−2	−2	+4	−3	+3	+4
1	−2	−1	−1	+1	−6	+6	−4	−1	−5	+4	+5
1	−2	+1	−2	−4	+1	0	+2	0	+4	+5	+1
0	+1	−1	0	+1	−2	+2	+2	+3	+2	+4	0
0	0	0	−1	−1	+2	+1	+1	−3	−2	−2	−5
1	+1	−1	−2	−2	−2	+2	0	+3	+3	−5	−1
0	−1	+1	−1	+1	+4	0	+5	+3	−1	−3	+1
4	−5	−2	+5	+4	−1	0	+4	−6	0	−1	+6
3	+1	−2	−2	+1	+1	−1	+5	+2	+2	+3	+1
0	+3	+2	−2	0	0	0	+2	−2	−9	+10	−4
1	0	0	+1	−1	+3	−1	+1	−7	+5	+6	−8
1	−3	−2	0	+1	+1	+1	+6	+6	−2	−3	−4
1	−2	−2	−1	+2	+6	−6	−5	−3	−8	−7	−4
1	−3	0	+2	−2	+2	−5	+2	−1	+4	−4	+2
2	+1	+3	0	−8	0	−1	+8	+2	−9	+7	+9
1	+3	−2	+2	0	+1	−2	+4	−2	+5	+4	−4
0	0	0	−1	+2	−3	−3	−3	+8	−5	−5	−11
5	+1	−2	−6	−8	+3	+4	−2	−8	−1	−10	−1
5	−1	−2	+4	−4	−1	−6	−3	+9	+6	−3	+12
0	−2	+2	+1	−3	+1	+2	−3	−2	−7	+8	+5
3	0	+4	−1	+5	−6	+7	+2	−1	+2	+5	−3
2	0	+2	0	−1	+4	+3	−1	+4	−3	−3	−7
3	+2	+4	+1	+1	−7	+1	0	−9	+2	−10	−2
2	+1	+2	+2	−1	+5	0	+3	+4	0	−1	+6
1	+3	+4	+1	−3	−4	−1	+1	−6	−5	+6	+5
3	+1	−2	+3	−2	+8	−6	+3	0	+2	+4	+2
2	−1	+1	−1	0	−3	−4	+3	0	−2	0	−4
2	−3	+1	−2	+2	+4	−7	+1	0	0	−1	−3
4	+5	−2	+6	−4	+3	+3	0	+3	+2	−2	+1
3	+1	0	+3	−2	−4	+2	0	+2	+2	−1	−4
0	+2	−2	0	−1	+2	−3	+3	−5	−5	−7	+3
2	−2	0	+4	−2	−3	−2	+2	+1	+3	+1	+3
0	−3	−3	+4	+1	+2	−3	0	+1	−5	+7	+1
0	0	0	−1	+4	−3	−6	−4	−1	+6	−2	−8
1	0	0	0	−1	0	+2	−1	−2	−3	−3	+3
1	0	+1	−1	0	−1	−1	−2	−3	0	−2	+3

Period.	41^s3.	41^c3.	55^s4.	55^c4.	69^s5.	69^c5.	28^s2.	28^c2.	sin 2D.	cos 2D.	[illegible]
86	− 4	− 6	+ 2	− 5	+ 1	− 4	+3	−1	−5	+ 3	[illegible]
87	0	− 3	+ 3	+ 3	0	+ 4	+1	+4	−5	+ 3	[illegible]
88	− 6	− 1	+ 5	+ 3	− 3	+ 4	+3	−5	−5	− 6	[illegible]
89	− 1	− 3	− 1	+ 1	− 1	− 1	+4	+2	+3	+ 7	[illegible]
90	− 3	− 1	− 2	+ 2	0	− 2	−5	−1	+3	+10	[illegible]
91	− 1	0	− 2	0	+ 2	− 1	0	+2	−1	+ 4	[illegible]
92	− 7	− 4	+ 2	− 8	− 7	+ 3	−3	+5	+2	+ 2	[illegible]
93	− 4	− 1	+ 3	− 3	− 4	− 3	+3	−4	+3	+ 3	[illegible]
94	− 4	0	+ 3	+ 2	+ 2	0	+3	+1	+5	− 1	[illegible]
95	− 4	− 1	− 3	+ 5	− 2	+ 5	−5	−1	+3	0	[illegible]
96	− 3	+ 2	− 3	+ 3	− 4	+ 1	+3	+3	+3	+ 2	[illegible]
97	+ 1	+ 6	− 1	+ 5	− 4	+ 2	−1	+2	−3	+ 2	[illegible]
98	+ 4	+ 2	− 2	+ 2	− 2	− 1	0	−1	0	0	[illegible]
99	+ 1	+ 8	− 3	− 8	+ 7	+ 4	+5	−3	−1	− 1	[illegible]
100	+ 2	+ 6	+ 3	− 5	− 3	+ 5	−4	−2	−2	− 2	[illegible]
101	− 2	+ 3	+ 2	+ 3	0	− 3	−2	+2	+1	0	[illegible]
102	+ 2	+ 5	+ 2	+ 5	+ 4	− 4	+2	−3	+1	− 4	[illegible]
103	+ 3	+ 4	− 2	+ 4	+ 3	+ 3	−1	−1	0	− 2	[illegible]
104	0	+ 3	− 2	− 1	− 2	0	−1	−2	+2	− 3	[illegible]
105	+ 2	+ 5	− 1	− 4	− 1	− 4	+1	0	+3	0	[illegible]
106	+ 2	+ 2	0	− 3	+ 2	− 2	−2	0	0	+ 1	[illegible]
107	+ 5	+10	+10	+ 3	− 1	+10	−3	+4	+2	− 2	[illegible]
108	+ 2	+10	− 2	+ 9	− 7	− 4	+4	+1	+1	+ 3	[illegible]
109	+ 1	+ 5	− 4	− 1	+ 4	0	+4	+2	+4	0	[illegible]
110	0	+ 8	− 3	− 6	+ 1	+ 6	−3	−4	+1	− 2	[illegible]
111	0	+ 3	+ 2	− 3	− 3	0	+3	+2	+4	− 2	[illegible]
112	+ 9	+ 8	+ 9	− 8	− 7	− 8	−1	−5	+5	− 4	[illegible]
113	+ 5	0	+ 5	− 1	+ 3	− 4	−4	0	−3	0	[illegible]
114	+11	− 5	+11	+ 6	+11	+ 4	+5	+7	−1	− 3	[illegible]
115	+ 9	− 6	+ 1	+11	− 4	+10	+3	−6	+1	0	[illegible]
116	+ 5	−11	− 5	+11	−10	+ 1	−4	+2	−3	+ 6	[illegible]
117	0	−10	− 9	+ 6	− 4	− 9	+7	−2	+2	+ 2	[illegible]
118	0	− 8	− 7	− 5	+ 9	− 1	−2	−6	−1	+ 2	[illegible]
119	− 3	− 6	− 3	− 6	+ 4	+ 6	+3	+5	+2	+ 4	[illegible]
120	− 6	− 8	+ 5	− 7	− 7	+ 2	−1	+1	+7	+ 5	[illegible]
121	− 7	− 1	+ 5	− 4	− 6	− 2	−3	+2	−2	+ 1	[illegible]
122	− 8	− 2	+ 5	+ 4	+ 5	− 2	−3	0	−3	+ 3	[illegible]
123	− 4	− 4	− 5	+ 5	− 2	+ 7	+5	+1	+3	+ 2	[illegible]
124	− 5	+ 2	− 3	+ 6	− 3	+ 6	−5	+3	+5	+ 1	[illegible]
125	− 4	0	− 4	− 3	− 1	− 4	+1	+2	−1	+ 4	[illegible]
126	− 1	+ 1	− 1	0	− 1	0	−2	0	+1	+ 2	[illegible]
127	+ 2	− 4	+ 1	+ 6	− 5	− 2	+5	−2	0	+ 2	[illegible]
128	− 4	− 7	− 2	+ 8	− 2	− 8	−5	0	+1	0	[illegible]
129	− 3	− 1	− 1	+ 3	+ 2	− 3	+2	0	+1	+ 1	[illegible]
130	− 7	− 3	− 7	− 2	+ 2	+ 6	+4	−2	+3	+ 2	[illegible]
131	− 6	+ 7	− 9	0	0	+ 8	0	+4	−4	+ 1	[illegible]
132	+ 1	+ 5	− 5	− 1	− 4	+ 3	+3	−2	0	0	[illegible]
133	− 1	+ 4	0	− 4	− 2	− 4	−5	+1	+4	− 2	[illegible]

45°3.	45°3.	77°5.	77°5.	31°2.	31°2.	64°4.	64°4.	49°3.	49°3.	64°3.	64°3.
−3	+3	+5	−6	+3	+7	+2	−1	−6	0	−1	−4
0	−2	0	+1	−1	−1	+4	+2	+3	+4	−2	−1
−3	+2	+1	+5	+4	−2	−3	−1	+6	−1	−2	−7
+2	−2	0	+3	+2	+1	+1	+2	0	+1	−1	0
−2	+4	0	+2	+2	+1	0	+7	+3	−3	−1	+3
−1	−2	0	+2	0	+2	+4	0	0	0	+1	−2
0	+6	−3	−2	+2	−1	+3	0	−1	0	+2	−1
−7	−3	−4	−3	+3	+2	−1	0	+2	+1	−1	+6
−2	−4	−1	+3	+2	−1	0	0	−2	−1	0	+1
0	+3	−2	0	0	+2	+1	+1	0	+3	−1	−2
−5	−4	−1	0	−1	0	+3	+4	−3	−5	+5	−2
0	−1	−2	−2	−1	−3	−4	−4	−2	−2	+1	+1
−2	+1	+2	−2	+1	+3	0	−1	−1	−2	+3	+3
+3	−3	+3	+1	−3	−1	+1	+2	0	+1	+1	+1
0	+2	−2	+2	+2	+1	0	0	−1	−2	+2	+2
−1	+2	−1	0	0	+2	+1	+2	−1	+2	+1	−1
+1	−1	−1	+1	−1	+1	0	+1	+1	−1	−1	−1
+3	−1	+1	−1	+1	0	−3	−1	−2	0	0	+3
0	+3	−3	0	+2	−4	−2	−1	−4	+1	0	−1
−6	−1	+4	−2	−2	+1	+1	+4	−3	+1	+2	+1
+1	−1	+2	−1	−1	−2	+2	0	+2	−2	+2	0
+1	+3	+1	+1	+2	0	+2	−2	+3	+3	−3	−1
0	0	0	−1	−1	−1	+2	0	−2	−4	−3	0
−1	+2	−2	0	−1	−2	0	+1	−3	−2	+1	−1
2	−3	−3	+2	−1	−4	+4	−4	−3	5	+3	+3
+6	0	+1	−3	−3	+3	+2	−4	+2	+4	−3	−8
−1	+7	+4	−1	−3	−5	−1	0	+6	0	−2	−5
+1	+1	0	+3	+2	+2	0	+4	−2	−5	−2	−1
+2	+3	−3	−4	−3	−5	−3	+6	−2	−1	+1	−3
−2	−3	0	−4	+4	−1	−4	+3	−1	−1	−2	+5
−6	−4	−7	−1	+4	−5	+4	−2	+1	−3	−1	−8
−3	−1	+1	+1	0	0	+5	0	−2	+6	−8	+3
−1	+2	+2	+5	+4	−4	−3	+1	−1	+3	+4	−3
+2	−3	+1	−3	−2	−2	−3	+1	+3	−1	+5	0
−4	−2	+1	+3	+1	+2	+6	0	+6	−3	−1	−1
+2	+2	−1	+2	−2	0	+4	+2	−5	−1	−1	−3
+2	−3	+1	+5	−3	−5	+4	+1	+3	−1	−2	−3
+2	+1	+2	−1	−3	+1	−2	+1	−1	0	+5	+2
+3	−3	+1	+1	0	−1	−2	−2	−3	−2	+1	−3
−1	−1	+1	−1	−1	−1	−1	+1	+5	−2	−1	+2
−3	0	+1	0	+2	0	−2	+1	−1	−1	+3	−1
0	−1	+3	+1	0	+3	+2	−3	−2	+5	+3	+3
+2	−1	0	+3	−2	−2	−1	−2	0	−1	0	−3
0	0	+2	0	−2	−1	+1	+2	−1	0	+2	+2
−1	−1	−6	0	+1	+5	−1	+1	−1	+1	−3	+2
+4	−3	−3	0	−2	+1	0	+2	0	−1	+1	−2
+2	+2	+2	+2	+1	+2	−2	0	−2	−2	−1	−2
+1	+1	0	0	0	+1	+2	+4	0	−3	+1	−1

Period.	$22^{a}1$.	$22^{c}1$.	$68^{a}3$.	$68^{c}3$.	$69^{a}3$.	$69^{c}3$.	$49^{a}2$
86	+3	−2	−7	−3	−5	+5	+ [illegible]
87	−1	0	−4	0	−5	−2	− [illegible]
88	+4	+3	+10	−6	−3	+12	− [illegible]
89	−3	0	−2	−2	+2	+2	− [illegible]
90	+3	+3	+2	−1	0	0	− [illegible]
91	−1	+1	0	0	−1	0	− [illegible]
92	−3	0	−2	+4	−2	−3	+ 1
93	+1	−2	+1	−2	−3	+1	0
94	0	+1	0	+1	+1	0	− [illegible]
95	−1	−1	0	−1	+1	−2	0
96	+4	+2	+5	+1	−3	+2	+ 1
97	+1	−1	0	−1	−1	+1	− [illegible]
98	−5	−4	+3	−1	+4	−1	+ 1
99	−1	+2	+4	+1	+2	+3	− 4
100	−2	−3	+1	−2	0	+1	0
101	+2	0	0	−1	0	0	+ 1
102	−2	0	+1	−3	−1	−3	− 4
103	−2	−2	−1	−1	+1	0	0
104	−2	0	+1	0	0	−1	+ 3
105	0	0	−1	−3	−2	+2	+ 3
106	+3	−3	+1	+5	+2	+4	+ 1
107	+2	−2	−1	−1	0	0	− 7
108	−1	−2	−4	0	+3	0	+ 2
109	+1	−3	−1	+2	+4	+3	− 2
110	−2	+4	−4	0	−4	+2	− 10
111	+2	+1	+3	+4	−3	+2	− 1
112	+7	−4	−3	−1	−1	+2	+ 4
113	−2	0	−2	−1	−1	+3	+ 2
114	−2	+2	0	−3	0	−2	− 1
115	−2	+3	0	−1	+2	+2	+ 3
116	+1	+7	+1	−3	+2	+4	0
117	−7	+1	−6	+1	+4	+6	− 2
118	−2	−5	−3	−2	−3	−2	− 4
119	−2	+4	0	−1	0	0	0
120	+3	0	+4	−1	−2	0	0
121	+4	+1	−4	+2	+3	+4	0
122	−1	0	+1	+6	0	+5	+ 4
123	−2	+1	+3	−2	−1	+1	+ 10
124	−1	−1	−2	−3	−1	+2	+ 2
125	0	+2	+2	+2	+3	+2	+ 6
126	−3	+2	0	−2	+2	0	+ 1
127	+4	−1	−3	−1	+1	−3	− 1
128	−4	+2	+3	−5	−5	+1	0
129	+2	−1	−4	0	−1	+4	− 2
130	+5	+1	0	+3	−1	+1	− 1
131	+1	−2	−2	+1	−1	−1	− 1
132	−1	−1	+2	0	−1	−1	− 1
133	+2	0	+1	−1	−1	−1	+ 1

$27^s 1.$	$27^c 1.$	sin D.	cos D.	$31^s 1.$	$31^c 1.$	$64^s 2.$	$64^c 2.$	$68^s 2.$	$68^c 2.$	$69^s 2.$	$69^c 2.$
−4	+4	+8	−12	−8	+2	+5	−4	+3	+3	−3	−6
−2	−4	+3	−7	−5	−3	−4	+3	+1	+3	+5	0
+1	−12	−2	−7	+2	+1	−3	−2	+4	+2	+2	−2
+4	−4	−8	−6	−4	+4	+4	0	−1	−2	0	−3
+1	−1	−5	−5	−4	+2	−4	+1	+4	+2	−1	+4
+3	+3	−1	−4	0	−2	+1	+1	−1	+2	0	−3
+1	+6	−4	−1	+3	−2	+1	−4	+1	+1	+1	−2
−2	−2	−6	−3	+2	−1	+1	+4	+2	0	−1	−2
+1	+2	−3	0	−1	−4	−6	+1	0	0	−1	−1
−5	−6	−4	+2	−1	+1	−2	−1	−2	+1	−3	−1
+9	−2	−3	+1	−4	+1	+1	−1	0	−3	+3	0
+2	+4	0	0	0	+2	−2	+2	+2	+3	−2	−1
−7	−4	+4	−2	−1	0	+1	−1	−6	−1	+3	+5
+9	+5	−3	0	−4	−2	+1	+3	+1	+4	+4	−1
−8	0	−1	+2	−1	−3	+2	−2	−2	+2	−1	+3
+6	−3	0	+2	−2	+1	+3	+1	+2	+1	0	+2
0	+7	−3	+6	+2	−2	0	−2	−1	0	0	0
−1	−2	−1	−3	0	0	−1	+2	−2	0	+1	−1
−2	−1	−2	−8	+5	−1	0	−1	−2	+5	+5	−2
−5	−1	−2	−14	−1	−3	0	0	+3	−4	−1	−4
+5	+3	−1	−11	−1	−2	0	+1	+1	+3	+1	+3
−8	+3	−2	−9	+3	0	+1	0	−3	−1	−2	−3
+8	−8	−2	−9	0	+3	+1	0	+2	+3	−2	+1
−3	+10	0	−10	−1	+4	0	+3	+3	+1	−2	0
−7	−4	+3	−9	+5	+1	0	+4	+2	+1	0	−2
+5	0	−2	−11	+6	−6	−7	0	+5	+3	+6	−3
−17	+3	−2	−11	−2	−1	−3	−1	+1	−2	+2	−1
+3	−12	−3	−3	+1	+7	−7	−2	+5	0	+4	+5
+3	+20	−1	−4	+7	−2	−2	−5	+4	+4	−5	0
−10	−7	−4	−6	+1	−2	+1	0	−2	−2	+2	+4
+14	+1	−2	−1	+2	−2	−3	+1	0	+3	+3	−2
−6	+14	+3	+8	−2	+3	−2	−1	−2	+7	+4	+4
−1	−8	−3	+6	0	+1	+1	0	−4	−3	−4	−4
0	+1	−1	+3	−2	−4	−2	−1	+5	−1	+3	+4
−6	−3	−5	−2	+6	−2	+4	+4	−4	−1	+4	−4
+7	−6	−3	+1	−2	−3	0	+4	−1	+1	+2	−2
−1	+9	+1	+6	−4	−7	0	−5	−4	−1	−1	+4
+1	−11	−7	0	−5	+5	+1	−4	−1	+2	0	+3
−1	−1	−8	+6	−4	+8	+4	+6	0	+4	−2	+3
0	−3	−5	−4	−2	−4	+4	0	0	−3	+2	0
+2	−2	+1	+1	−1	+2	+2	−1	−1	0	+2	0
−1	+3	−6	+6	−1	−1	+1	0	+6	+2	−6	−4
+8	+2	−3	+5	+1	−3	+1	+3	−3	−4	−4	+4
−2	+6	−6	−3	+2	−1	+1	−1	−1	−4	−3	−2
−4	−5	−2	−4	−1	+5	−3	−1	+2	+2	+1	+2
+11	0	+6	−2	−2	−1	+1	+1	−2	−1	+1	−2
−1	+5	+1	+2	−1	−2	−4	+1	+2	+5	−3	−5
−3	−5	−5	+3	+3	0	−2	0	−1	0	+1	−1

95	+2	− 3	+
96	0	+ 3	−
97	+2	− 2	−
98	+2	− 1	+
99	+1	− 3	+
100	+1	0	+
101	+1	+ 2	−
102	−1	− 1	
103	+3	− 2	+
104	+1	0	+
105	+7	− 3	+
106	0	− 1	+
107	+3	− 1	−
108	−1	+ 3	−
109	+2	+ 2	−
110	+2	+ 4	−
111	−2	− 3	−
112	−1	+ 3	
113	−2	+ 4	+
114	0	− 3	+
115	+8	− 1	+
116	−5	+ 3	+
117	0	− 6	+
118	+2	+ 2	−
119	−3	− 4	−
120	−2	+ 2	−
121	+3	+ 7	+
122	+1	− 2	+
123	−2	+ 1	+
124	−4	− 1	−
125	−1	+ 2	+
126	−1	[illegible]	[illegible]

TABLE VII.

parison for Solar Terms in Moon's Latitude of Observed with Theoretical Coefficients.

Argument.					Coefficient of Hansen's Tables. Sine.	Apparent Correction. Sine.	Apparent Correction. Cosine.		Concluded Coefficient.		Brown's Coefficient. *M.N.* lxv. pp. 286–291.	Argument. g.	g′.	ω.	ω′.
	g′.	F.	D.		″	″	″		″		″				
	0	1	4	+	1·19	−0·11	−0·03	+	1·1	+	1·19	5	−4	5	−4
	0	1	2	+	117·24	+0·04	+0·03	+	117·3	+	117·26	3	−2	3	−2
	0	1	1	−	5·41	+0·17	+0·40	−	5·4	−	5·36	2	−1	2	−1
	0	1	0	+	18461·65	−0·27	−0·72	+	18461·3		(+18461·48)	1	0	1	0
	0	1	−1	+	4·91	+0·09	+0·33	+	4·9	+	4·80	0	1	0	1
	0	−1	2	+	623·71	−0·05	+0·05	+	623·7	+	623·66	1	−2	1	−2
	0	−1	3	−	0·35	+0·05	0·00	−	0·3	−	0·35	2	−3	2	−3
	0	−1	4	+	3·68	−0·06	−0·07	+	3·6	+	3·68	3	−4	3	−4
	0	1	4	+	0·21	−0·01	+0·04	+	0·2	+	0·21	6	−4	5	−4
1	0	1	2	+	15·12	+0·01	−0·01	+	15·1	+	15·12	4	−2	3	−2
1	0	1	1	−	0·67	−0·09	−0·02	−	0·7	−	0·67	3	−1	2	−1
1	0	1	0	+	1010·01	+0·17	−0·03	+	1010·2	+	1010·18	2	0	1	0
1	0	1	−1	+	0·47	−0·16	−0·05	+	0·4	+	0·43	1	1	0	1
1	0	1	−2	−	166·58	−0·03	+0·04	−	166·6	−	166·58	0	2	−1	2
1	0	−1	3	−	0·30	−0·01	−0·05	−	0·3	−	0·31	1	−3	2	−3
	0	−1	4	+	6·58	−0·05	+0·07	+	6·6	+	6·58	2	−4	3	−4
	0	−1	6	+	0·09	+0·03	+0·01	+	0·1	+	0·10	4	−6	5	−6
	0	1	4	+	3·00	−0·08	+0·05	+	2·9	+	3·00	4	−4	5	−4
	0	1	3	−	0·21	+0·05	+0·04	−	0·2	−	0·21	3	−3	4	−3
	0	1	2	+	199·46	+0·04	−0·01	+	199·5	+	199·49	2	−2	3	−2
	0	1	1	+	0·12	−0·04	−0·05	+	0·1	+	0·14	1	−1	2	−1
	0	1	0	−	999·53	−0·19	0·00	−	999·7	−	999·70	0	0	1	0
	0	−1	1	−	0·61	+0·05	−0·04	−	0·6	−	0·59	1	−1	0	−1
	0	−1	2	+	33·37	−0·01	0·00	+	33·4	+	33·36	2	−2	1	−2
	0	−1	4	+	0·47	0·00	0·00	+	0·5	+	0·48	4	−4	3	−4
	1	1	2	−	1·28	−0·11	+0·07	−	1·4	−	1·27	3	−1	3	−2
	1	1	1	+	0·81	+0·11	+0·01	+	0·9	+	0·80	2	0	2	−1
	1	1	0	−	6·48	−0·06	−0·08	−	6·5	−	6·49	1	1	1	0
	−1	−1	2	+	29·73	0·00	+0·02	+	29·7	+	29·69	1	−3	1	−2
	−1	−1	4	+	0·41	+0·06	0·00	+	0·5	+	0·42	3	−5	3	−4
	−1	1	4	+	0·16	−0·02	0·00	+	0·1	+	0·15	5	−5	5	−4
	−1	1	2	+	7·99	+0·05	−0·01	+	8·0	+	8·00	3	−3	3	−2
	−1	1	0	+	4·87	+0·01	+0·04	+	4·8	+	4·86	1	−1	1	0
	−1	1	−1	−	0·80	−0·15	−0·14	−	0·9	−	0·81	0	0	0	1
	1	−1	2	−	12·14	+0·12	+0·15	−	12·1	−	12·14	1	−1	1	−2
	1	−1	4	−	0·10	−0·09	+0·01	−	0·1	−	0·11	3	−3	3	−4
	0	3	2	−	0·14	+0·01	+0·07	−	0·1	−	0·14	5	−2	5	−2
	0	3	0	−	6·30	+0·06	−0·01	−	6·2	−	6·30	3	0	3	0
	0	3	−2	−	2·15	−0·04	−0·04	−	2·2	−	2·19	1	2	1	2

Ref. No.	Argument. g.	g′.	F.	D.	Coefficient of Hansen's Tables. Sine.	Apparent Correction. Sine.	Cosine.	Concluded Coefficient.	Brown's Coefficient. M.N. lxv. pp. 286–291.	Arg… g. g′.
					″	″	″	″	″	
6	2	0	1	2	+ 1.52	−0.03	+0.04	+ 1.5	+ 1.52	5−2
25	2	0	1	0	+61.89	−0.05	−0.05	+61.9	+61.91	3 0
43	2	0	1	−1	+ 0.11	+0.07	+0.01	+ 0.1	+ 0.11	2 1
65	2	0	1	−2	−15.57	−0.01	−0.09	−15.6	−15.57	1 2−
82	−2	0	−1	4	+ 0.64	+0.03	−0.01	+ 0.7	+ 0.64	1−4
35	−2	0	1	4	+ 2.42	+0.03	−0.05	+ 2.4	+ 2.41	3−4
78	−2	0	1	2	− 1.62	+0.02	+0.01	− 1.6	− 1.62	1−2
72	2	0	−1	0	+31.76	−0.09	−0.01	+31.7	+31.76	1 [illegible]
30	2	0	−1	2	+ 2.15	−0.01	+0.02	+ 2.1	+ 2.15	3−2
12	1	1	1	2	− 0.26	+0.05	+0.02	− 0.2	− 0.24	4−1
24	1	1	1	1	+ 0.10	−0.05	−0.02	+ 0.1	+ 0.10	3 0
42	1	1	1	0	− 5.33	+0.02	−0.01	− 5.3	− 5.33	2 1
85	1	1	1	−2	− 7.47	0.00	−0.08	− 7.5	− 7.46	0 3−
62	−1	−1	−1	4	+ 0.52	+0.16	+0.03	+ 0.6	+ 0.60	2−5
19	−1	−1	1	4	+ 0.35	0.00	−0.02	+ 0.3	+ 0.34	4−5
56	−1	−1	1	2	+ 8.91	−0.06	+0.10	+ 8.9	+ 8.90	2−3
93	1	1	−1	0	− 5.10	−0.02	−0.07	− 5.1	− 5.10	0 1−
52	1	1	−1	2	− 0.83	−0.05	+0.09	− 0.9	− 0.83	2−1
16	1	−1	1	2	+ 1.16	−0.02	0.00	+ 1.1	+ 1.14	4−3
51	1	−1	1	0	+ 6.76	+0.02	+0.09	+ 6.8	+ 6.76	2−1
92	1	−1	1	−2	+ 0.80	+0.01	−0.02	+ 0.8	+ 0.80	0 1−
57	−1	1	−1	4	− 0.15	+0.01	−0.05	− 0.1	− 0.17	2−3
49	−1	1	1	2	− 1.32	+0.03	+0.07	− 1.3	− 1.32	2−1
90	−1	1	1	0	− 5.66	+0.04	+0.04	− 5.6	− 5.66	0 1
59	1	−1	−1	2	+ 1.78	+0.05	−0.02	+ 1.8	+ 1.77	2−3
83	0	−2	−1	2	+ 1.10	−0.02	+0.05	+ 1.1	+ 1.10	1−4
36	0	−2	1	2	+ 0.39	−0.04	−0.02	+ 0.4	+ 0.39	3−4
71	0	2	−1	2	− 0.13	−0.08	−0.12	− 0.2	− 0.14	1 0
10	1	0	3	0	− 1.02	−0.04	+0.01	− 1.0	− 1.02	4 0
40	1	0	3	−2	− 0.33	+0.04	−0.03	− 0.3	− 0.33	2 2
13	−1	0	3	2	− 0.25	+0.01	−0.09	− 0.2	− 0.24	4−2
44	−1	0	3	0	− 2.79	0.00	+0.10	− 2.8	− 2.81	2 0
86	−1	0	3	−2	+ 0.29	0.00	−0.03	+ 0.3	+ 0.29	0 2
1	3	0	1	2	+ 0.14	−0.05	+0.04	+ 0.1	+ 0.14	6−2
11	3	0	1	0	+ 3.98	−0.03	−0.05	+ 4.0	+ 3.98	4 0
41	3	0	1	−2	− 1.52	+0.01	−0.02	− 1.5	− 1.52	2 2−
89	3	0	−1	−2	− 0.27	−0.04	+0.01	− 0.3	− 0.26	0 2−
48	3	0	−1	0	+ 1.59	−0.02	−0.06	+ 1.6	+ 1.59	2 0−
15	3	0	−1	2	+ 0.15	−0.06	−0.04	+ 0.1	+ 0.15	4−2

Argument. *g*.	*g'*.	F.	D.	Coefficient of Hansen's Tables. Sine.	Apparent Correction. Sine.	Cosine.	Concluded Coefficient.	Brown's Coefficient. *M.N.* lxv. pp. 286–291.	Argument. *g*.	*g'*.	*ω*.	*ω'*.
2	1	1	0	−0″·64	−0″·01	−0″·01	−0″·6	−0″·64	3	1	1	0
2	1	1	−2	−0·66	−0·01	+0·02	−0·7	−0·66	1	3	−1	2
−2	−1	1	4	+0·22	−0·04	+0·03	+0·2	+0·22	3	−5	5	−4
2	1	−1	0	−0·31	−0·06	+0·05	−0·4	−0·31	1	1	−1	0
2	−1	1	2	+0·13	0·00	−0·02	+0·1	+0·11	5	−3	3	−2
2	−1	1	0	+0·80	−0·09	−0·01	+0·7	+0·81	3	−1	1	0
2	−1	−1	0	+0·32	−0·01	+0·02	+0·3	+0·30	1	−1	−1	0
2	−1	−1	2	+0·12	+0·09	+0·01	+0·2	+0·13	3	−3	1	−2
1	2	1	−2	−0·28	+0·03	+0·02	−0·3	−0·27	0	4	−1	2
−1	−2	1	2	+0·32	+0·03	+0·01	+0·3	+0·32	2	−4	3	−2
1	−2	1	0	+0·14	−0·13	0·00	0·0	+0·12	2	−2	1	0
−1	2	−1	2	−0·10	−0·01	−0·07	−0·1	−0·11	0	0	1	−2
−1	2	1	2	−0·12	+0·03	+0·05	−0·1	−0·12	2	0	3	−2
−1	2	1	0	−0·11	−0·05	0·00	−0·1	−0·10	0	2	1	0
2	0	3	0	−0·12	−0·05	+0·10	−0·2	−0·12	5	0	3	0
−2	0	3	0	+0·11	+0·07	−0·01	+0·2	+0·13	1	0	3	0
4	0	1	0	+0·26	0·00	−0·03	+0·3	+0·27	5	0	1	0
4	0	1	−2	−0·13	0·00	0·00	−0·1	−0·14	3	2	−1	2

Table VIII.

Comparison for Figure of Earth Terms in Moon's Latitude of Observed with Theoretical Coefficients.

Ref. No.	Argument.	Coefficient of Hansen's Tables. Sine.	Cosine.	Apparent Correction. Sine.	Cosine.	Hill's Coefficient.
97	g + F − (− ☊)	−0″·48	...	0″·00	−0″·08	−0″·45
98	F + (− ☊)	−0·35	...	+0·05	+0·06	−0·35
99	F − (− ☊)	−8·26	+1·66	+0·13	−0·13	−8·73
100	2D − F + (− ☊)	...	...	+0·04	−0·03	−0·32
101	− g + F − (− ☊)	+0·48	...	+0·03	−0·13	+0·49

fluctuation of the mean error, such as may be introduced by change of refraction, instrumental errors, &c. Multiplication by $2\cdot2 \cos D + 1\cdot1$ instead of by cos D eliminates these fluctuations, and retains any periodicity in the coefficient of cos D such as may arise from a term of the form $g - g' + \omega$, for example. For this reason also it was necessary to investigate the coefficient of $\sin (g - g' + \omega)$ with D as the auxiliary angle.

D is, for numerical purposes, taken as ${}_{57}A_2$, or an angle which goes through two revolutions in fifty-seven lunar days. Its epoch is, however, adjusted every period, so as to keep D = 0 corresponding to new moon. Every other auxiliary angle has its

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Each quantity was
mean approximate
F used during the
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the observed. Thi
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Hansen's tables is n
therefore, to verify

I wish to call at
No. 94, Table VII.,
and the correction t
the observations is
argue from this t
principal figure of E
are real, and are far
of observers or other

Lastly, as to the
that Table VI. con

divided by 192 is 0″·005, a negligible quantity. Although, therefore, the other columns of Table VI. have not been subjected to so searching a test, I believe the results as given in Tables VII. and VIII. may be relied on to within the accidental errors due to the observations.

On the Discordant Values of the Principal Elliptic Coefficient in the Moon's Longitude. By P. H. Cowell.

The values given for the coefficient of the principal elliptic term in the Moon's longitude have varied from 22637″·15 of Hansen's theory to 22641″·6 of Airy's tabular places. In the present note I take some of the values published during the last half-century, and I try as far as possible to trace the discordances to their source. The values in question are—

Ref. No.	Author.	Coefficient.	Material.	Reference.
		″		
1	Airy	22639·06	Greenwich 1750–1851	*Memoirs R.A.S.* xxix. p. 13.
2	Newcomb	·82	„ 1847–1858	Corrections to Hansen's Tables, p. 29.
3	„	·50	Greenwich and Washington 1862–1874	„ „
4	Nevill	·32	Greenwich 1862–1877	*Memoirs R.A.S.* xlviii. p. 417.
5	Cowell	·54	„ 1750–1851	*Monthly Notices*, vol. lxv. p. 147.
6	„	·46	„ 1847–1901	„ „

I shall establish the propriety of the following corrections to the above values:

Ref. No.	Solar Correction.	Planetary Corrections.	Corrected Value.
	″	″	″
1	+0·16	...	22639·22
2	−0·25	+0·06	·63
3	−0·25	+0·10	·35
4	+0·05	+0·06	·43
5	...	...	·54
6	...	...	·46

It will be seen that the accordance of the six values is improved by these corrections. The range is reduced from 0″·76 to 0″·41, or, leaving out Airy's result, from 0″·50 to 0″·28.

One of my values (Ref. No. 5) is based upon the same observed places as Airy's, and the discordance is not therefore due to errors of observation. Either Airy's analysis or mine is wrong.

Airy obtains his result by finding a correction, $-2''\cdot54$, to the value used in his tabular places. As Airy divides his observations into two groups only, each group covering a range of 180° in the mean anomaly, and as the coefficients of some of his terms are over $3''$ in error, an error of 10 per cent. in his correction is intelligible, and in examining the accordance of various results Airy's may therefore be left out of account. Airy, in fact, missed a great opportunity. He had material with which any short-period coefficient could certainly be obtained to within $0''\cdot2$ (see my result, Ref. No. 5), and for 1 per cent. additional to the labour actually expended in the reductions he might have given observed values for all coefficients several years in advance of equally good theoretical ones; and if he had taken a year, instead of nine years, as his unit of analysis, he could not have failed to anticipate Professor Newcomb's discovery of the *Jupiter* evection term.

I will now explain the foregoing corrections. The solar corrections are intended to reduce the results to what would have been obtained if the coefficients $-8''\cdot44$ and $+18''\cdot55$ had been used for the terms $\sin(g+D)$ and $\sin(g-D)$. Both Airy and Professor Newcomb have overlooked the necessity of combining a consideration of these two terms with a discussion of the eccentricity of the Moon's orbit. Airy was fortunate in so far that the errors of the coefficients of the terms $\sin(g\pm D)$ employed by him are far smaller than those of many of his other coefficients. Hansen had published in the *Darlegung* a large correction to the coefficient of $\sin(g-D)$ before Professor Newcomb made his investigations. That the values above quoted for the coefficients in question are final may be inferred from the fact that Hansen's, Delaunay's, and Professor Brown's theories and my own observed values are in close agreement.

In *Memoirs R.A.S.* vol. xlviii. p. 315 Mr. Nevill points out that a term (in the notation of Hansen and Professor Newcomb) $\delta B \sin(g'+D)$ will produce an apparent effect $-\delta B\times 0\cdot70 \sin g'$. He arrives at the factor $-0\cdot70$ by supposing that the observations are uniformly distributed from first quarter to last quarter. I employ the factor $-0\cdot48$ obtained as the mean value of $\cos D$. Mr. Nevill nowhere states the point in question in more general terms than in the above special case, but I conclude that he has in fact corrected his result for the error $0''\cdot60 \sin(g-D)$ in the course of pp. 315–318 of his memoir. The small correction I have therefore applied to his result represents an error $0''\cdot10 \sin(g+D)$ only.

Coming now to the planetary corrections, results Nos. 1, 5 need no correction, as the observations extend over 100 years. In No. 6 the results extend over fifty-four years, and the planetary terms have already been applied to the individual tabular places. Therefore No. 6 needs no correction either. Also results 5 and 6 cover 150 years between them, and as they are in close agreement, the presumption is that there exists no undiscovered term capable

of affecting the result. Planetary corrections have, therefore, only to be applied to Nos. 2, 3, 4.

(1) $+0''\!\cdot\!316 \sin(g+2\varpi-3J+7^\circ)$ calculated by M. Radau, and in *Monthly Notices*, lxv. p. 135, shown to be confirmed by the observations. The term was unknown to Professor Newcomb and to Mr. Nevill.

Ref. No.	Mean Epoch.	Value of $2\varpi-3J+7^\circ$.	θ.	Coefficient multiplied by $\frac{\sin\theta}{\theta}$.	Correction.
		$^\circ$	$^\circ$	$''$	$''$
2	1853·0	60	58	+0·27	−0·13
3	1868·5	270	63	+0·26	0·00
4	1870·0	255	77	+0·22	+0·06

The first line of the above table reads as follows:

Professor Newcomb's investigation (Ref. No. 2) has a mean epoch 1853·0 when the value of $2\varpi-3J+7^\circ$ takes the value 60°. During the period over which the investigation extends, $2\varpi-3J+7^\circ$ varies from $60^\circ+58^\circ$ to $60^\circ-58^\circ$. The correction required is therefore $-0''\!\cdot\!316\,\frac{\sin 58^\circ}{58^\circ}\cos 60^\circ = -0''\!\cdot\!13$.

(2) $-1''\!\cdot\!1 \sin(g+2\varpi-2J)$. This is the *Jupiter* evection term discovered by Professor Newcomb, and attributed to the action of *Jupiter* by Mr. Nevill. Mr. Nevill uses $-1''\!\cdot\!4$ as the coefficient, and the correction consequently required by his result is insensible. The coefficient $-1''\!\cdot\!1$ is indicated by the observations 1750 to 1901, whereas Dr. G. W. Hill and M. Radau agree in giving $-0''\!\cdot\!9$ as the theoretical coefficient.

The term was discovered by Professor Newcomb as a wave of $17\frac{1}{2}$ years from crest to crest in the values of the coefficients of $\sin g$ and $\cos g$, as given by two investigations extending over twelve and thirteen years respectively. Under these circumstances a high degree of accuracy was of course unattainable. Professor Newcomb gives as the empirical term

$$-1''\!\cdot\!5 \sin(g+253^\circ\!\cdot\!2+21^\circ\!\cdot\!6\,(t-1868\cdot 5))$$

The means of the values of h, exhibited by Professor Newcomb on p. 28 of his paper, are $+0''\!\cdot\!40$ from 1847 to 1858, and $+0''\!\cdot\!54$ from 1862 to 1874; to these means Professor Newcomb applies corrections $-0''\!\cdot\!07$ and $+0''\!\cdot\!11$ respectively for his empirical term, thus obtaining $+0''\!\cdot\!33$ and $+0''\!\cdot\!65$ (p. 29); the corrections resulting from the actual term (calculated as in the case of the term $+0''\!\cdot\!316 \sin(g+2\varpi-3J+7^\circ)$) are $-0''\!\cdot\!22$ and $+0''\!\cdot\!03$ respectively. Hence his resulting values of the principal elliptic coefficient require correction on this account,

Ref. No.	Correction.
	$''$
2	+0·15
3	+0·08

) $-0''\cdot68 \sin(g+2\varpi+3V-5E)$. This is a *Venu*
d by M. Radau. Its verification from the o
l very troublesome, as there is a periodic ter
h the errors with argument, Moon's longitude
bly arising from an erroneous tabular lunar para
gains one revolution a century upon the *Venu*
nthly Notices, vol. lxv. pp. 136 and 148, I have
ng its coefficient at $0''\cdot7$. These two terms we
d by Professor Newcomb at the time when he
upiter evection term, because about the year
rms as nearly as possible cancel each other. C
two terms I have applied the following correcti

ef. No.	Correction for *Venus* Term.	Correction for Empirical Term.	Su
2	$+0''\cdot12$	$-0''\cdot08$	+0
3	$-0\cdot11$	$+0\cdot13$	+0

e corrections are small, partly because the ter
and partly because the length of the wave int
ues of the coefficients of $\sin g$ is nine years, and
ore thoroughly eliminated from a twelve or thi
ion than a seventeen year term is.
s worth noting that though the two terms cance

rofessor Newcomb's two results. Professor Newcomb's second sult and Mr. Nevill's are now in close agreement, as is only ıtural seeing that Mr. Nevill's sixteen years include the ıirteen years of Professor Newcomb's second result. The discord-ıce has been decreased from 0″·18 to 0″·08 by the calculations ! this paper.

Tote on Diurnal Variations of the Nadir and Level of the Transit Circle at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

In a former paper communicated to the Society in 1899 [arch it was shown that when the observations of the level and adir taken at different times of the same day were compared ith each other, those observations made about 6 P.M. showed iscordances from those made about midday and midnight. The resent paper continues these comparisons of the level and nadir ear noon, 6 P.M., and midnight for the years 1897–1904. The esults for these times are derived from about 100 days in each ear in which one observation at least falls within the limits of ach group, viz. 9^h–15^h, 15^h–21^h, and 21^h–23^h civil time. In rder to carry the discussion through the whole twenty-four ours, observations made between 3^h–9^h have been compared rith those obtained between 15^h–21^h on the same or the previous ays. There are approximately thirty days in each year when uch observations have been made. The results are given in the ollowing table :

Diurnal Changes of Level and Nadir for the years 1897–1904.

Year.	Level.				Nadir.			
	Noon.	6 p.m.	Midnight.	6 a.m.	Noon.	6 p.m.	Midnight.	6 a.m.
	″	″	″	″	″	″	″	″
1897	+0·20	·00	+ ·13	+ ·30	+ ·11	·00	+ ·17	+ ·33
1898	+0·33	·00	+ ·23	+ ·36	+ ·16	·00	+ ·11	+ ·05
1899	+0·29	·00	+ ·18	+ ·30	+ ·17	·00	+ ·19	+ ·24
1900	+0·29	·00	+ ·23	+ ·46	+ ·14	·00	+ ·05	+ ·02
1901	+0·28	·00	+ ·26	+ ·31	+ ·17	·00	+ ·09	+ ·06
1902	+0·21	·00	+ ·20	+ ·34	+ ·20	·00	+ ·17	+ ·09
1903	+0·14	·00	+ ·22	+ ·32	+ ·04	·00	+ ·09	+ ·06
1904	+0·27	·00	+ ·29	+ ·55	+ ·06	·00	+ ·15	+ ·12
Mean	+0·25	·00	+0·22	+0·37	+0·13	·00	+0·13	+0·12

The variation of the level has a period of 24^h with its maximum about 6 A.M. and minimum about 6 P.M. The variations of the nadir are much smaller, and do not show any conclusive result except the discordance near 6 P.M.

[redacted] the air. The consequence of this neglect, h
[redacted] enith-distances, thus reduced, contain systema
[redacted] eriod. Since, so far as I know, attention
[redacted] alled to this point, a brief dissertation on th
[redacted] atter may not be quite out of place.

[redacted] Let ρ be the density of the air at the pl
[redacted] a constant, and put

$$\frac{c\rho}{1+2c\rho}=a \tag{1}$$

[redacted] en the refraction for the apparent zenith-dist
[redacted] represented by the series

$$\text{(2)}\quad \text{Refraction} = \frac{a}{\sin 1''}(a_0 \operatorname{tang} z - a_1 \operatorname{tang}$$

[redacted] The value of the coefficient a varies with
[redacted] r. If the density of the air have the value ρ_0

$$\frac{c\rho_0}{1+2c\rho_0}=a_0 \tag{3}$$

[redacted] en the result is at once

$$a=\frac{\rho}{\rho_0}\,\frac{a_0}{1-2a_0\left(1-\frac{\rho}{\rho_0}\right)} \tag{4}$$

[redacted] therefore, the real value for any density of
[redacted] e value of a for each density can be compute
[redacted] own and the temperature besides, the sum of
[redacted] y also be ascertained. The density is found

and taking for the unit of density the density of dry air at 0° Celsius, under pressure of one atmosphere (column of mercury 760 mm.), if B is the reading of the barometer (millimetres), τ the reading of the interior thermometer (Celsius), h the height of the point of observation above sea-level, expressed in metres, and ϕ its geographical latitude, then the air-pressure, p, follows from the formula

$$(5) \quad p=(1-0{\cdot}000000196h-0{\cdot}00265 \cos 2\phi)\frac{B}{760}(1-0{\cdot}000162\tau)$$

The air constantly contains a certain amount of vapour. According to the researches of Dalton, the pressure of a mixture of air and vapour, at the temperature t, is equal to the sum of their separate pressures at the same temperature. Therefore, if p be the pressure of the damp air (which can be obtained from the reading of the barometer by the foregoing formula) and if π be the pressure of the vapour contained in the air, then $p-\pi$ is the pressure which the dry air alone exerts. According to the Gay-Lussac–Mariotte law, however, the quotient for dry air

$$\frac{\text{Pressure}}{\text{Density} \times (1+at)}$$

where $a = 0{\cdot}003663$ (Regnault) is the expansion coefficient of dry air, is a constant. As for $p = 1$ and $t = 0°$ C. the density is to be $= 1$, so must the above-mentioned constant be equal to 1; hence the equation is for dry air at the temperature t

$$(6) \qquad \text{Density} = \frac{\text{Pressure}}{1+at}$$

If, therefore, we indicate the density of the dry air of the temperature t, and under the pressure $p-\pi$ by ρ_1, we have

$$\rho_1 = \frac{p-\pi}{1+at}$$

If the vapour of the temperature t, whose pressure is indicated by π, be replaced by dry air of the temperature t, which exerts the same pressure π, the density of this air, according to equation (6), would be equal $\frac{\pi}{1+at}$. Experiment, however, shows that the weight of a volume of vapour is only 0·622 of the weight of an equal volume of dry air at the same temperature and pressure, and therefore, for like temperature and like pressure, the density of the vapour is also 0·622 of the density of the dry air; and we have for the density ρ_2 of the vapour

$$\rho_2 = 0{\cdot}622\frac{\pi}{1+at}$$

Now the density of the damp
and writing the previously ascerta

$$\rho = \frac{p - c}{1 \cdot}$$

or if 0·378 be replaced by $\frac{3}{8}$

$$(7) \qquad \rho = p \frac{1 -}{1 +}$$

If the vapour pressure be ex
height of a mercury column, whos
the humidity contained in the
column of mercury be likewise i
from equation (5), and from the
vapour pressure, that in equation
and from the same equations (5) a
value of a, we obtain

$$\rho = \frac{B}{760} \frac{1 - 0{\cdot}000162\tau}{1 + 0{\cdot}003663t} (1 - c$$

or

$$(8) \ \rho = \frac{B}{760} \frac{1 - 0{\cdot}000162t}{1 + 0{\cdot}003663t} [1 - 0\cdot$$

For B = 760mm, $\tau = 0°$, $h =$
for the density

$$(9) \qquad \rho_0 = 1\cdot$$

Professor Bauschinger gives for v
$\alpha_0 = 60''{\cdot}15 \sin 1''$. We have

$$\frac{1 - \frac{3}{8}\frac{\frac{\pi}{B}}{6}}{1 - \frac{3}{8}\frac{6}{760}} = 1 + \frac{3}{8}$$

If we put

$$(10) \ B[1 - 0{\cdot}000000196h - 0{\cdot}00$$

we find from the equations (8) and

$$(11) \qquad \frac{\rho}{\rho_0} = \frac{\beta}{760} \frac{1}{1}$$

To form a serviceable table for the calculation of refraction we can now compute the quotient $\frac{\rho}{\rho_0}$ for a series of equidistant values of β and t, and then from (4) [by the help of $\frac{\rho}{\rho_0}$ and $a_0 = 60''\cdot 15 \sin 1''$ corresponding to ρ_0] we have the values of a; and when these are found the refractions corresponding to the adopted series of values of β and t can be calculated by (2). In order, therefore, to draw from the table thus obtained the refraction corresponding to the observed values of B, t, τ and π, there is the correction

$$\tfrac{3}{8}\left(6\frac{B}{760}-\pi\right)$$

to be applied to the indicated barometrical height B, besides the corrections dependent on h, ϕ, and $t-\tau$. The influence which this class of corrections has on refraction may easily be calculated by the aid of M. Radau's tables. The table marked I. by M. Radau indicates the mean refraction; Table II. gives, together with the arguments, zenith distance, and temperature, the variation of the mean refraction for 1° C., this variation—supposing that it is always taken as negative—is to be multiplied by t and added to the mean refraction. From Table IV., with the argument, mean refraction + correction for temperature, we can at length derive the variation of the refraction which corresponds to the change of 1^{mm} of the barometer. If this variation be multiplied by $\tfrac{3}{8}\left(6\frac{B}{760}-\pi\right)$ the required influence of the vapour pressure on refraction is the result.

I now give a list of the monthly means of π and t, which has been compiled from the observations of Professor Bauschinger in Munich (1891–93) and of Dr. Grossmann * in Vienna-Ottakring (1896–98):

	Munich. π	t	Ottakring. π	t
	mm.	°	mm.	°
January	1·8	−12	...	
February	4·1	+ 1	3·9	+ 1
March	4·1	+ 3	4·2	+ 6
April	4·3	+ 7	5·7	+ 9
May	8·2	+14	8·9	+14
June	9·6	+14	10·4	+19
July	10·5	+17	...	
August	9·1	+14	12·7	+19
September	9·5	+12	10·4	+16
October	7·0	+ 7	7·1	+ 9
November	5·0	+ 1	4·0	+ 2
December	3·7	− 2	3·9	0

* "Beobachtungen am Repsoldschen Meridiankreise der von Kuffnerschen Sternwarte in den Jahren 1896–98," *Sitzungsberichte der königl. Sächsischen Gesellschaft der Wissenschaften*, Band xxvii. No. 1.

If we write $\frac{3}{8}(6-\pi)$ instead of $\frac{3}{8}\left(6\,\frac{B}{760}-\pi\right)$, which, however, is not strictly correct, we get for the influence of vapour pressure on refraction, at the zenith distances 55°, 65°, 70°, 75°, the following values :

	Munich.				Vienna-Ottakring.			
	55°.	65°.	70°.	75°.	55°.	65°.	70°.	75°.
	″	″	″	″	″	″	″	″
January	+0·19	+0·29	+0·37	+0·50	...	...	...	...
February	+0·08	+0·12	+0·15	+0·20	+0·09	+0·14	+0·18	+0·23
March	+0·08	+0·12	+0·15	+0·20	+0·08	+0·12	+0·15	+0·20
April	+0·07	+0·10	+0·13	+0·17	+0·01	+0·02	+0·02	+0·03
May	−0·09	−0·13	−0·16	−0·22	−0·11	−0·18	−0·23	−0·31
June	−0·14	−0·21	−0·26	−0·36	−0·18	−0·26	−0·32	−0·43
July	−0·18	−0·27	−0·34	−0·46	...	...	...	...
August	−0·13	−0·19	−0·24	−0·34	−0·27	−0·40	−0·50	−0·67
September	−0·14	−0·21	−0·27	−0·36	−0·18	−0·26	−0·32	−0·45
October	−0·04	−0·07	−0·08	−0·11	−0·04	−0·06	−0·08	−0·11
November	+0·04	+0·07	+0·09	+0·12	+0·08	+0·12	+0·15	+0·20
December	+0·10	+0·15	+0·20	+0·26	+0·09	+0·14	+0·18	+0·23

The errors arising from the neglect of the vapour pressure are noticeable even in the mean zenith distances ; they have moreover for the two specified series of observations from November to April the opposite signs to those from May to October. The zenith distances, without the corrections for vapour pressure, are too small in winter and too great in summer. The previously calculated corrections of refraction on account of vapour pressure can be represented by $f+x \sin\odot + y \cos\odot$, where x and y are functions of the zenith-distances. By way of example we have for Munich and $z = 75°$ (under the supposition that the corrections hold good for the middle of the month) the following formula: Correction $= -0''\cdot03 - 0''\cdot34 \sin\odot + 0''\cdot21 \cos\odot$. Supposing, then, the influence of moisture to have been omitted in the computation of refraction, the declinations (derived from the zenith-distances) of stars observed south of the zenith and the declinations concluded from the observations of northern stars at their lower culminations require a positive correction if observed in winter and a negative correction if observed in summer ; and these statements must be reversed for stars in upper culmination observed north of the zenith.

Besides the influence of damp here considered, there is still another effect which indeed almost disappears at $z = 75°$, but is noticeable at greater zenith-distances, and must be alluded to in this reference to M. Radau's memoir, *Essai sur les Réfractions Astronomiques*, pp. 16, 17. On the other hand we must not fail to mention that M. Radau on the strength of the experiments of

Fizeau and Jamin, comes to the conclusion that the equation (7) should be replaced by

$$(7a) \qquad \rho = p^{\,1-\frac{1}{8}\frac{\pi}{p}} \frac{}{1+at}$$

At the present time there are only two papers* published, in which, by means of astronomical observations, an attempt has been made to decide the question whether the formula (7) or (7a) is to be employed for the density of the air. Even if both investigations lead to the result that the former formula is to be preferred, yet a renewed examination of the question on the basis of the materials collected at other observatories is very desirable. In the meantime the corrections calculated by the writer, adopting formula (7), may be of interest.

Vienna-Ottakring: 1905 *June* 15.

On the Formula connecting Diameters of Photographic Images with Stellar Magnitude. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. The measures of the Oxford portion of the Astrographic Catalogue being now completed, it is possible to formulate certain conclusions as to the behaviour of the different plates in portraying stellar images. Early in the history of the work it was decided to record the diameters of the stellar images as an indication of the magnitude, and this was done throughout. But discussion of the results was deferred until a large amount of material had been accumulated.

2. The diameter of each star disc was estimated in units of $0''\cdot3$ in both positions of the plate, and the mean of the two estimates has been set down. No great precision is claimed for these estimates, and they are affected by a number of circumstances such as the following:

(*a*) Personal habits of the different measurers in estimating the limits of the ill-defined disc.

(*b*) Elongation of images near the corners of the plate. The observer was instructed to take the mean of the two diameters.

(*c*) Differences in intensity of image for the faint stars. In place of an estimate of diameter we have, then, an estimate of faintness.

3. In addition to these difficulties of interpreting the actual record on the plate, there is a systematic change in the impression

* Bauschinger, "Untersuchungen über die astronomische Refraktion," *Annals of the Munich Observatory*, vol. iii.; Courvoisier, "Unters. üb. die astr. Refr.," *Publications of the Heidelberg Observatory*, vol. iii.

a star of given magnitude according to its di
re of the field. This change was studied by
by counting the number of stars photograp
istances from the centre of the plate (see *Mont*
p. 434). It was found that the star density
reatest at the centre of the plate, but reached
33′ from the centre, and that the density wa
ween 40 and 100, equivalent to something like
de. Hence to interpret the records of diame
rate measures of stellar magnitude for all sta
e would require a number of investigations fo
been possible to find the time. The records
l as an approximate guide to the magnitude.
n adopting a formula to convert the dian
mate magnitudes we therefore look, first of a
since we cannot hope for any great accuracy
de was of a simple linear formula,

$$\text{Diameter} = 13(10{\cdot}8 - \text{magnitude}),$$

estimated diameters of all the Cambridge sta
o $+31°$ were compared with theoretical diam
om this formula.

TABLE II. Zone + 26°.

Camb. Mean Mag.	Theoretical Diameter.	Error of Formula. Defective Plates.	Excessive Plates.
7·0	49·4	−10·9	+12·4
8·5	29·9	− 7·7	+10·1
9·3	19·5	− 6·8	+ 6·2

The error of diameter seems to be partly proportional to the diameter itself, and thus to represent the "defective" plates we must write

$$\text{Diameter} = 11{\cdot}7\,(10{\cdot}4 - \text{magnitude})$$

instead of the normal

$$\text{Diameter} = 13{\cdot}0\,(10{\cdot}8 - \text{magnitude})\,;$$

while for the "excessive" plates we have

$$\text{Diameter} = 16{\cdot}1\,(10{\cdot}9 - \text{magnitude}).$$

These formulæ, that is to say, give approximately the same residuals as the mean formula gives for the normal plates, as is shown in Table III.

TABLE III. Zone + 26°.

Mean Mag. Camb.	Defective Plates Obs.	Calc.	O−C.	All Plates. Obs.	Calc.	O−C.	Excessive Plates. Obs.	Calc.	O−C.
7·0	38·5	39·8	−1·3	48·3	49·4	−1·1	61·8	62·8	−1·0
8·5	22·2	22·2	0·0	30·6	29·9	+0·7	40·0	38·6	+1·4
9·3	12·7	12·9	−0·2	19·4	19·5	−0·1	25·7	25·8	−0·1

7. If the above formulæ were strictly applicable, no star fainter than magnitude 10·4 could be shown on the "defective" plates; and indeed if the smallest recognisable diameter be taken as 4, this would give 10·1 as the magnitude of the faintest stars on the plate. Similarly for the "normal" plates we should have $D = 4$ when $m = 10{\cdot}5$, and for the "excessive" plates the faintest stars would be about 10·65. Now from independent considerations it seems probable that these limiting magnitudes are too low, and that the formula cannot be extended to magnitude 11·0.

8. The first natural thought is that the curvature indicated by the three residuals gives us the clue. We have done wrong to take a linear formula, and should have allowed for a slight curvature. But examination shows that the curvature indicated by the residuals is in the *wrong direction.* If we assume a formula between D, the diameter, and m, the magnitude, such as

$$D = a + bm + cm^2$$

(which is, of course, a purely empirical formula merely adopted to

ce a curvature), and find a, b, c so as to give
ers at magnitudes 7·0, 8·5, 9·3 as above, we ge

$$D = 7{\cdot}4 + 3{\cdot}7m - m^2$$

vanishes when $m = 10{\cdot}5$ instead of when
Indeed, without any calculation it is clea
ls after magnitude 9·3 become increasingly
ed diameters are too small. If the plates reall
r than is indicated by these linear formulæ w
urvature in the *opposite direction.*
We are led to consider the scale of visual
d for reference. They are those of the Caml
and were assigned as follows :

The circle observer, standing near the pointer
the observing catalogue and transit clock
ts the telescope for the coming star, clan
unces the magnitude of the star. . . . The tran
finally calls out to the circle observer his esti
itude of the star, and any remark that may
al for future reference."—[P. (6) of Introducti
ge A.G. Cat. + 25° to + 30°.]

actually change the *curvature* of the relation between magnitude and diameter from one direction to the other. So far as we have gone the linear relation seems to be very near the truth within the limits concerning us, and if there is any curvature it would seem to be probably in the direction opposite to that first indicated.

12. The linear formula first mentioned and part of the discussion of plates in zone $+26°$ based on it represent the preliminary work of some years ago. Recently, since the completion of the measures of all zones, the diameters of zone $+31°$ were compared with the same formula, viz.

$$\text{Diameter} = 13\,(10{\cdot}8 - \text{magnitude}).$$

The circumstances had meanwhile changed in several essentials; the measurers were new, and the plates were believed to have increased in sensitiveness. The developer for zone $+31°$ was always Eikonogen, but for more than half zone $+26°$ Hydrokinone was used. The dome had been renewed with a larger opening which may have affected the plates in some way (*e.g.* the telescope was more easily shaken by wind, though there was less danger of cutting off a part of the object-glass by oversight). Possibly the observer was more skilled in guiding, and there was certainly greater reluctance to take photographs on poor nights. For all these reasons a change in the formula would not be surprising; and one satisfactory result of the comparison declared itself at once—there were no seriously defective plates, *i.e.* none with defect as much as 5.

13. The mean plate for zone $+31°$ when referred to the original formula

$$D = 13\,(10{\cdot}8 - \text{mag.})$$

had an excess of $+4$; and the observed diameters for the three groups are given in the second column of Table V. In the next two columns are given the corrections to two formulæ L (26) and L (31), viz.

$$D = 10{\cdot}0\,(11{\cdot}8 - m) \quad \ldots \quad \ldots \quad \ldots \quad \text{L}\,(26)$$

which was found at the end of § 10 for the observations of zone $+26°$ with residuals $+0{\cdot}3$, $-1{\cdot}4$, $+0{\cdot}4$; and

$$D = 8{\cdot}6\,(12{\cdot}7 - m) \quad \ldots \quad \ldots \quad \ldots \quad \text{L}\,(31)$$

which is the best linear formula for zone $+31°$.

Table V. Zone $+31°$.

Mean Corrected Mag.	Observed Diam.	O−C. L (26).	O−C. L (31).	O−C. Zone +26.
7·0	49·4	+1·4	+0·4	+0·3
8·6	34·0	+2·0	−1·2	−1·4
9·9	24·4	+5·4	+0·3	+0·4

[T]he residuals for the two zones suggest a cu[rve of]
[th]e same amount. Let us form an estimate of i[t]
[us]ing a formula

$$O - C = a + b(m-8\cdot6) + c(m-8\cdot6)^2$$

[th]e values

$= -1\cdot3 \qquad b = +0\cdot4 \qquad c = +$

[foun]d to satisfy both sets of residuals fairly well
[th]e value of c is not very well determined.
[thes]e values, the linear formulæ should be replaced

$$D = 30\cdot7 - 9\cdot6(m-8\cdot6) + 0\cdot8(m-8\cdot6)^2 \ldots$$
$$D = 34\cdot0 - 8\cdot2(m-8\cdot6) + 0\cdot8(m-8\cdot6)^2 \ldots$$

[N]ow the expressions on the right are not perfe[ct]
[the]y are not very different from perfect squa[res]
[...]t of $(m-8\cdot6)^2$ should in the first case be $0\cdot75$ a[nd]
[c]ase $0\cdot50$. If they had been perfect squares
[ta]ken the square roots and reduced the formul[æ]

$$\sqrt{D} = p - qm$$

TABLE VI.

Corrected Mean Mag.	Zone +26°. Observed $\surd$D.	Calculated *m*.	O–O.	Zone +31°. Observed $\surd$D.	Calculated *m*.	O–O.
7·0	6·95	6·98	−0·02	7·03	6·93	−0·07
8·6	5·53	8·60	0·00	5·83	8·60	0·00
9·9	4·41	9·87	−0·03	4·94	9·74	−0·06

17. The fact that the formula does not quite suit the Oxford results is thus exhibited in another way: the extreme residuals agree, but the middle one differs. The differences are not large when expressed in terms of magnitude, and a slightly different hypothesis as to the systematic errors of magnitude would smooth them out. We may proceed on the assumption that the law is sufficiently good for trial.

18. But attention is arrested by the difference in values of *n*. We should be prepared for a difference between Greenwich and Oxford, but there is an equal or greater difference between the two Oxford zones. What is this due to? We may obtain information by studying the valuable material given in the Greenwich Introduction.

19. Putting, then, the Oxford results aside for a time, we proceed to examine the formulæ on pp. xxviii–xxx of the Greenwich Introduction a little more closely to see if the variations exhibited in the constants *a* and *n* of the formula

$$m = a - n\sqrt{d}$$

are entirely accidental. It is readily seen that for a given exposure the constants *a* and *n* increase together. Collecting the results into groups they may be arranged as follows:

TABLE VII. (Greenwich).

Expos. 40ᵐ. No. of Plates.	Mean *a*.	Mean *n*.	Expos. 6ᵐ. No. of Plates.	Mean *a*.	Mean *n*.	Expos. 3ᵐ. No. of Plates.	Mean *a*.	Mean *n*.	Expos. 20ˢ. No. of Plates.	Mean *a*.	Mean *n*.
5	16·9	0·92	7	14·4	0·84	3	13·7	0·88	2*	12·4	0·85
9	16·1	0·85	8	13·4	0·75	1	13·0	0·70	...	...	...
5	15·2	0·75	6	12·4	0·63	3	12·2	0·66	6	11·1	0·75

20. The general result is that for all exposures when *a* changes by 1·0, *n* changes by 0·10 in the same direction. If we plot *m* and $\surd d$ as abscissa and ordinate, the formulæ represent a series of straight lines of different slope; but since the equation to one may be converted into that of any other by adding or subtracting a multiple of $1{\cdot}0 - 0{\cdot}10\surd d$, which vanishes when $d = 100$, all the lines for a given exposure will pass through the same point given by this value of *d*. If we consider the portions of the lines on the side of this point corresponding

* There is a printer's error, which makes it impossible to assign one of the values of *a*.

discs and faint stars, we naturally regard t
rior in quality which show faint stars well—
lue of $\sqrt{d}$ for a given value of m, and those
e faint stars have small discs or are lost. Bu
back to the point of intersection, we come
tars with discs the same in all cases ; and cro
de of this point we see that stars brighter
hich *increase* in size on nights when faint st
vious suggestion is that the variations w
with arise chiefly from *travelling of images* r
bsorption of light or failure in sensitivene
r from either of the last two causes all stars
in the same direction, while with unsteady i
understand both the loss of faint stars and t
f the diameters of bright ones.

Thus adopting (as is done on p. xxx of the
ction) the formula

$$m = 13{\cdot}7 - 0{\cdot}77\sqrt{d}$$

ean formula for six-minute exposures, we may
his to a good or bad night by writing

$$m = 13{\cdot}7 - 0{\cdot}77\sqrt{d} + v(10 - \sqrt{d})$$

where T is the time of exposure and $b = 2{\cdot}5$ (assuming Pogson's scale of magnitudes), then taking 6^m as the unit of time, we get the following values for c:

		c
40^m	$16{\cdot}1 - 2{\cdot}5 \log 6{\cdot}67 = 16{\cdot}1 - 2{\cdot}1 =$	$14{\cdot}0$
6^m	$13{\cdot}7 - 2{\cdot}5 \log 1{\cdot}00 = 13{\cdot}7 - 0{\cdot}0 =$	$13{\cdot}7$
3^m	$12{\cdot}9 + 2{\cdot}5 \log 2{\cdot}00 = 12{\cdot}9 + 0{\cdot}8 =$	$13{\cdot}7$
20^s	$11{\cdot}5 + 2{\cdot}5 \log 18{\cdot}00 = 11{\cdot}5 + 3{\cdot}1 =$	$14{\cdot}6$

23. But if we reduce the formulæ to the same value of n (say $0{\cdot}80$ which is nearly the mean value) the first terms are altered and the values of c come out as below:

		c
40^m	$15{\cdot}7 - 2{\cdot}1 =$	$13{\cdot}6$
6^m	$14{\cdot}0 - 0{\cdot}0 =$	$14{\cdot}0$
3^m	$13{\cdot}3 + 0{\cdot}8 =$	$14{\cdot}1$
20^s	$11{\cdot}6 + 3{\cdot}1 =$	$14{\cdot}7$

The values of c now progressively increase instead of changing irregularly as before; and this supports the view that it is right to reduce the formulæ to the same value of n in this way. But the progressive increase indicates that the value of b in the formula

$$a = c + b \log T$$

is *not* $2{\cdot}5$, but more nearly $2{\cdot}0$. If we adopt the value $2{\cdot}0$ for b the values of c would be accordant, thus:

		c
40^m	$15{\cdot}7 - 1{\cdot}6 =$	$14{\cdot}1$
6^m	$14{\cdot}0 - 0{\cdot}0 =$	$14{\cdot}0$
3^m	$13{\cdot}3 + 0{\cdot}6 =$	$13{\cdot}9$
20^s	$11{\cdot}6 + 2{\cdot}5 =$	$14{\cdot}1$

Hence to obtain one magnitude fainter we must increase the exposure time in the ratio

$10^{0{\cdot}5}$ instead of the ratio $10^{0{\cdot}4}$

i.e. in the ratio $3{\cdot}16$ „ „ „ $2{\cdot}51$

24. Some such conclusion has been several times stated before, *i.e.* it has been declared that prolonging the exposure $2{\cdot}5$ times did not give another magnitude; and the Greenwich results seem to prove it clearly. As the reduction to the same value of n may not be generally accepted, however, I have examined the point in a different manner.

25. There are three plates (Nos. 6200, 6202, 6204) on which four exposures of 40^m, 6^m, 3^m, and 20^s were given, from which it is possible to determine the relation between m and T under specially favourable conditions. Let us take, for instance, plate

The relationships found between m and d
ume as follows:

		$d=9$	$d=$
$T = 40^m$	$m_1 = 14{\cdot}6 - 0{\cdot}77\sqrt{d} =$	12·3	6·
$T = 6^m$	$m_2 = 12{\cdot}0 - 0{\cdot}53\sqrt{d} =$	10·2	6·
$T = 3^m$	$m_3 = 11{\cdot}9 - 0{\cdot}66\sqrt{d} =$	9·9	5·
$T = 20^s$	$m_4 = 10{\cdot}8 - 0{\cdot}68\sqrt{d} =$	8·8	4·

m these we can find the magnitude of a star
er for each exposure, as exhibited in the last
ues of $d = 9$ and 100 respectively. If now w

$$m = c + b \log T$$

d c and b by least squares, we obtain for

Plate 6200,	$d = 9$	$m = 10{\cdot}61 + 1{\cdot}65 \log T$
	$d = 100$	$m = 5{\cdot}84 + 1{\cdot}43 \log T$
Plate 6202,	$d = 9$	$m = 11{\cdot}63 + 2{\cdot}20 \log T$
	$d = 100$	$m = 6{\cdot}50 + 1{\cdot}86 \log T$
Plate 6204,	$d = 9$	$m = 10{\cdot}95 + 1{\cdot}89 \log T$
	$d = 100$	$m = 5{\cdot}39 + 2{\cdot}11 \log T$

exposure of 40^m affects the short exposures in the manner indicated we ought to get a different progression in the value of c in the two cases.

To test the point the mean formulæ given in the Greenwich Introduction were formed and compared as follows :

TABLE IX. (Greenwich).

	Plates 6200, 6202, 6204 (with exposure of 40^m).	Plates 6160, 6168, 6178 (short exposures only).
	m	m
6^m	$12{\cdot}8-0{\cdot}67\sqrt{d}$	$12{\cdot}7-0{\cdot}66\sqrt{d}$
3^m	$12{\cdot}7-0{\cdot}73\sqrt{d}$	$12{\cdot}7-0{\cdot}72\sqrt{d}$
20^s	$11{\cdot}0-0{\cdot}75\sqrt{d}$	$11{\cdot}1-0{\cdot}76\sqrt{d}$

The accordance is so good that it seems improbable that the long exposure had any effect, and this avenue of escape from the conclusion that we must increase the exposure time in a ratio considerably greater than 2·51 seems closed.

30. Is it possible that the scale of visual magnitudes is wrong? Why should not the photographic evidence that a light is doubled be as good as that obtained by visual methods, which are equally liable to pitfalls? The method of equalising two lights by use of a Nicol prism is certainly liable to systematic error from internal reflexions, as was pointed out by Dr. Spitta many years ago (*Monthly Notices R.A.S.*, vol. l. p. 325). Unfortunately for this explanation, the errors he dealt with are in *the other direction*. He found that when light was increased in a known ratio of 8 to 1 the erroneously evaluated wedge gave a *greater* ratio of 16 to 1 ; we find that when the light is increased in a known ratio by photographic exposure we get too *small* an apparent effect on the visual scale. This loophole of escape seems also closed.

31. I must not omit to refer to the paper by the Astronomer Royal (*Monthly Notices R.A.S.*, vol. lii pp. 125–146) in which he arrived at a conclusion at variance with that reached above—viz. that the value of b was sensibly 2·5, and not 2·0, or that to obtain one magnitude the exposure must be prolonged 2·512 times, and not 3·1 times. The value he obtains for the prolongation is actually 2·675, which is greater than 2·512, but not so large as 3·1. It is the mean of six values, 3·00, 2·80, 2·89, 2·06, 2·87, and 2·43, and the Astronomer Royal himself remarks that there is something curious about the plates giving the small results 2·06 and 2·43, which obviously affect the mean considerably. The evidence cannot, however, be neglected, though it is doubtful whether it can stand against the much greater mass of evidence given in the Greenwich Introduction.

32. It is perhaps not necessary to dwell further on this point, for it was twelve years ago admitted by Sir W. Abney that the law was liable to fail (see *Monthly Notices R.A.S.*, vol. liv. p. 65). He did not give very definite indications how the liability to fail was to be estimated, and it would seem as though we must

epend simply upon trial. Is it possible that
a preliminary exposure to faint light by t
lates, which is known to increase their se
eneral effect of such a preliminary exposure
nsidered in § 27; the short exposures w
vourably compared with the long, as they s
do.

33. Whatever the reason, we seem to
npirical process, that for the Greenwich res
e following general formula:

$$m = c + 2{\cdot}0 \log T - n\sqrt{d} - v(10-$$

here c and n are absolute constants, when
ecided what conditions of steadiness to adopt
depends on the night. Thus if we adopt $n =$
the Greenwich volume, we find from a
rmulæ

$$c = 13{\cdot}7$$

ithin 0·1, and the general formula may be wri

$$m = 13{\cdot}7 + 2{\cdot}0 \log T - 0{\cdot}77\sqrt{d} - v(10-$$

TABLE X.

Zone + 26°; Plates 0–800; Developer Hydrokinone; Old Dome.

Group.	No. of Plates.	Mags. 7·0 and 9·9. n.	a.	Mag. 8·6. a.
I.	10	1·13	13·88	13·82
II.	10	1·04	13·83	13·86
III.	10	1·00	13·74	13·63
IV.	10	1·14	14·62	14·56
V.	10	1·16	14·86	15·04
VI	10	0·98	14·27	14·31
VII.	7	1·07	15·32	15·03
Mean ...	67	1·07	14·36	14·32

TABLE XI.

Zone + 26°; Plates 800–1557; Developer Eikonogen; Old Dome.

I.	10	1·12	14·06	14·06
II.	10	1·19	14·53	14·44
III.	10	1·19	14·84	14·69
IV.	10	1·17	14·77	14·68
V.	10	1·25	15·30	15·43
VI.	10	1·26	15·38	15·57
VII.	15	1·13	14·96	14·95
VIII.	10	1·25	15·78	15·78
IX.	10	1·18	15·47	15·55
X.	10	1·21	15·98	16·19
XI.	10	1·34	16·93	17·24
Mean ...	115	1·21	15·27	15·33

TABLE XII.

Zone + 29°; Plates 0–800; Hydrokinone; Old Dome.

I.	13	1·03	14·11	14·12
II.	13	1·08	14·71	14·83

TABLE XIII.

Zone + 29°; Plates 800–1557; Eikonogen; Old Dome.

I.	10	0·99	13·59	13·49
II.	10	1·00	14·08	13·92
III.	10	1·10	14·57	14·66
IV.	10	0·92	13·81	13·72
V.	10	1·07	14·68	14·60
VI.	10	0·96	14·24	14·11
VII.	10	1·01	14·50	14·58
VIII.	13	0·97	14·60	14·66
Mean ...	83	1·00	14·26	14·22

TABLE XIV.

Zone +29°; Plates 1558 to 2360; Eikonogen; New D

Group.	No. of Plates.	Mags. 7·0 and 9·9. n	a
I.	16	1·18	15·17
II.	16	1·22	15·74
III.	16	1·31	16·86

TABLE XV.

Zone +30°; Plates 800–1557; Eikonogen; Old Do

I.	8	1·10	14·01
II.	8	1·11	14·60

TABLE XVI.

Zone +30°; Plates 1557–2360; Eikonogen; New D

I.	10	1·23	15·27
II.	10	1·27	15·74
III.	10	1·18	15·27
IV.	10	1·14	15·11
V.	10	1·35	16·44
VI.	10	1·32	16·16

more than 1·0, and from analogy with Greenwich we should expect a progressive change of 0·10 in the coefficient of *d* or 0·14 in that of D (see § 20). We do not find it. But taking the mean results for each table and arranging them in order we get Table XVIII.:

TABLE XVIII.

Table.	No. of Plates.	n	a	$0·141\ a-n$.
XIV.	83	1·00	14·26	1·00
XIII.	26	1·05	14·40	0·98
XI.	67	1·07	14·36	0·96
XVI.	16	1·10	14·30	0·91
XII.	115	1·21	15·27	0·96
XV.	48	1·24	15·92	1·00
XVII.	143	1·26	16·12	1·01
XVIII.	158	1·36	16·59	0·98

in the last column of which the value of 0·141 $a-n$ is calculated, and is seen to be approximately constant. The question is therefore raised whether the variations shown by the Greenwich results can be attributed to accidental causes, or are not systematic in some way.

36. *Developer.*—The change from Hydrokinone to Eikonogen made little difference. Taking the two zones which have plates of both kinds:

TABLE XIX.

Zone.	Hydrokinone.			Eikonogen.		
	Table.	No. of Plates.	n	Table.	No. of Plates.	n
$+26°$	XI.	67	1·07	XII.	115	1·21
$+29°$	XIII.	26	1·06	XIV.	83	1·00

the change goes opposite ways in the two cases. Moreover, though the values of n for zone $+31°$ (developer Eikonogen) are large, those for $+30°$ with the same developer are small.

37. *New Dome.*—Some change seems to have taken place with the erection of the new dome. Possibly the wider shutter-opening may have affected the plates, or they may have come up to a different focal reading after the dismounting of the object-glass during the operations.

TABLE XX.

Zone.	Old Dome.			New Dome.		
	Table.	No. of Plates.	n	Table	No. of Plates.	n
$+29°$	XIV.	83	1·00	XV.	48	1·24
$+30°$	XVI.	16	1·10	XVII.	143	1·26

But there must be also some other cause of change to explain the difference between zone $+30°$ and zone $+31°$. At this point attention was drawn to the possible influence of the particular

The difference of 6 ı
in estimating the positi
estimations of diameter ‹

38. To test the point
into three groups acco
measured nearly all the]
Gray (E.A.G.), and Mr.
plates were divided int
general check on the resı

Zone

Group.	No. of Plates.
I.	10
II	10
III.	10
IV.	10
V.	7
Mean ...	47

Zone +

VI.	10
VII.	10

TABLE XXIII.

Zone $+31°$. Measurer, F.H.S.

Group.	No. of Plates.	Mags. 7·0 and 9·9. n	a	Mag. 8·6. a
XII.	10	1·14	15·19	15·00
XIII.	10	1·38	16·88	16·77
XIV.	10	1·41	17·11	17·03
XV.	8	1·14	15·34	15·18
Mean ...	38	1·27	16·13	16·00

39. The value of n thus changes sensibly from one measurer another. For B.G., and to a less extent for E.A.G., its value mes out large. Hence we can explain the large value of n for ne $+31°$ as compared with zone $+26°$ at least *partially*; for ne $+26°$ was practically completed before B.G. and E.A.G. came the observatory. But, on the other hand, we cannot attribute e whole of these differences to personality, particularly that :tween zone $+30°$ ($n = 1·24$, see § 49) and zone $+31°$ $= 1·36$, see § 46); for the measurers were practically the me in the two zones, viz.

	B.G.	E.A.G.	F.H.S.	Others.
Zone $+30°$, No. of Plates	47	42	35	36
Zone $+31$ "	47	55	38	20

40. Indeed it is very difficult to explain the difference tween these two zones. The plates for both were practically taken with the new dome, and the measurers were approxi- ately the same. Are the visual magnitudes compared with the otographic measures systematically different? As already marked, those for zone $+31°$ are Argelander's unchanged, while ose for zone $+30°$ are somewhat modified by some Cambridge timations, which are used for one half the plate. For Arge- ider we have adopted the correction $+0·6$ to magnitude 9·3; d if D and D′ be the measured diameters of stars of magnitude ɔ and 9·3 on Argelander's scale we find from zone $+31°$

$$\sqrt{D} - \sqrt{D'} = (9·9 - 7·0)/n = 2·9/1·36 = 2·13$$

the different value of n is attributable to the fact that the rrection to the 9·3 stars for zone $+30°$ is not $+0·6$ but $+x$ en

$$2·13 = (2·3 + x)/1·24$$
$$x = 0·34$$

nce nearly half of the stars on plates in zone $+30°$ are Leiden ırs with Argelander's magnitudes unchanged, the correction r the remaining (Cambridge) stars must be nearly zero to make e general mean 0·34. It thus seems probable that only a part the difference in the value of n can be explained by a 'stematic difference in the visual magnitudes.

found to be 1·30, se
concluded that wit
effect from this cau

42. It may also
were grouped accor
upon R.A. could be

43. To sum up t
the changes in the

may be ascribed *par*

(A) Changes in

(B) Some alterat
wider shutter openi
between O.G. and p

(C) Possible sys
Leiden magnitudes.

(D) Change of d

(E) Change of al

(F) Right Ascen
have no appreciable

44. As regards
material for discussi
vol. lxiv. p. 440, the
of *R Cygni*, in whi
plate of one hour's
The results may be g

Hagen's Mag.	No. of Stars in Group.

45. In the last two columns two different values of the ficient of D are tried : the larger value 1·35 suits the groups tars better, but the two individual bright stars are better ed by the smaller value. Owing to the fact that individual s may be coloured (the first star is almost certainly coloured, Hagen gives magnitude 4·9, while the Rousdon magnitude ·4) we cannot decide between the values of n by any numerical ess. The mean formula found in § 46 for zone + 31° was

$$m = 16{\cdot}5 - 1{\cdot}36\sqrt{D}$$

ch for a 60^m exposure should become

$$m = 16{\cdot}5 + b \log 10 - 1{\cdot}36\sqrt{D}$$

we equate this to the formula found on the supposition ; $n = 1{\cdot}36$

$$m = 18{\cdot}4 \qquad - 1{\cdot}36\sqrt{D}$$

itting the two bright stars in finding the constants) we get

$$b = 1{\cdot}9$$

ch is in sensible agreement with the Greenwich result. But in we must not attach much weight to a single plate.

46. In a paper on Nova *Persei* Mr. Bellamy has compared measured diameters of stars round it with Hagen's magnitudes *nthly Notices*, vol. lxi. pp. 479–80). The results are fairly l suited (excluding the faintest stars) by the formula

$$m = 15{\cdot}2 - 1{\cdot}36\sqrt{D}$$

the exposures were short and not available for a determina- . of the coefficient of log T.

47. When Nova *Geminorum* was discovered, three long osure plates (100^m, 35^m, and 30^m) were taken of the region *Monthly Notices*, vol. lxiii. pp. 326, 512). The diameters ı number of stars were measured at the time, but the infor- ion was not given in detail. The diameters of corresponding s in the three plates were recently re-measured by F.H.S. se stars whose visual magnitudes are given by Hagen were ıped according to his estimations as follows :

TABLE XXV.

Nova Geminorum Plates.

p. No. of Stars.	Hagen Mag.	$\sqrt{\text{Diam.}}$			$m + 1{\cdot}20\sqrt{D}$.			$m + 1{\cdot}10\sqrt{D}$.		
		100^m.	35^m.	30^m.	100^m.	35^m.	30^m.	100^m.	35^m.	30^m.
4	7·7	8·5	7·4	7·4	17·9	16·6	16·6	17·1	15·8	15·8
5	8·3	8·3	7·2	7·1	18·3	16·9	16·8	17·4	16·2	16·1
6	8·9	7·2	6·4	6·3	17·5	16·6	16·5	16·8	15·9	15·8
6	10·3	6·6	5·2	5·0	18·2	16·5	16·3	17·6	16·0	15·8
7	11·0	6·0	4·7	4·5	18·2	16·6	16·4	17·6	16·2	16·0
13	11·4	5·4	4·0	3·7	17·9	16·2	15·8	17·3	15·8	15·5
7	11·7	5·0	3·6	3·3	17·7	16·0	15·7	17·2	15·7	15·3
				Mean...	18·0	16·5	16·3	17·3	15·9	15·7

be smaller than 1·0 ; 1
those of zone +31°,
measurer (F.H.S.) ge
E.A.G. his value fou
as low as 1·14. On
tabulate as correspondi

m	log T.
6	0·00
30	0·70
35	0·76
100	1·22

The coefficient of l
exposures is 2·4/1·22
smaller value when com
a larger value when co

(A) In §§ 1–6 the
the plates of zone +2
Catalogue are compared

Diame

with which they nearly
Cambridge A.G. Catalog
of Argelander. Residu
magnitude 7·0, 8·5, 9·3
middle group *exceeds* i
about 1·3 unit = 0″·4.

(B) This excess is

(D) But the values of n differ, not only Oxford from Greenwich, but zone $+26°$ from zone $+31°$. We turn first to the Greenwich published results to investigate such differences (§§ 16–18).

(E) At Greenwich, for a given exposure, a and n seem to vary together (§ 19). It is suggested that a variable term

$$v(10-\sqrt{d})$$

where d is measured in units of $0''{\cdot}15$ may be added or subtracted to the mean formula, according to the quality of the night.

(F) Reducing to the same value of n the formulæ given in the Greenwich Introduction for different exposures (40^m, 6^m, 3^m, 20^s), it is found that the constant a may be written

$$a = c + 2{\cdot}0 \log T$$

where c is independent of the time of exposure T. This corresponds to the following proposition: *When the time of exposure is prolonged in the ratio of five star magnitudes the photographic gain is four magnitudes* (§ 23).

(G) A few points are examined to see whether any explanation of this apparent loss can be found, but without success (§§ 27–33).

(H) Returning to the Oxford results, the plates in several zones are analysed to throw light on the changes in n. It is found (§§ 35–43) that n changes with the measurer, and with some alteration at the erection of the new dome; but not with developer, altitude at exposure, R.A. There is also some unexplained change between zones $+30°$ and $+31°$.

(J) Although n does not change very much with a for plates taken under similar conditions, systematic changes in n, owing to change of conditions, follow changes in a, as in (E) above at Greenwich (§ 35).

(K) The coefficient $2{\cdot}0$ for log T, as in (F) above, is confirmed by such evidence as the scanty material for studying long exposures at Oxford offers (§§ 44–48).

University Observatory, Oxford:
1905 *May* 27.

Determinations of Stellar Parallax from Photographs made at the Cambridge Observatory. Introductory Paper. By Arthur R. Hinks, M.A., and Henry Norris Russell, Ph.D.

§ 1. Our purpose in the present paper is to give a general account of the investigations of stellar parallax undertaken at Cambridge with the Sheepshanks Equatorial in 1903. In that

planned a considerable scheme, which wa
n forthwith owing to the appointment of
R.) as a research assistant to the Carnegie
which the first results are now available.
seems therefore to be appropriate for an i
of the work. Two years' experience of th
n has shown us that it works well, and
come up to the standard of internal agreemen
But since we hope that the work will be co
ears, we should value present criticisms of
l by us, so that they may not come too late t
ourselves of them.

In making our plans we kept two main

o secure the most advantageous relation b
of labour to be expended and the probab
esults to be achieved.

o eliminate at any cost all known sources of

these led to the adoption of certain rules for
ay be briefly discussed as follows :

r careful consideration we decided not to adop
n's plan of accumulating exposures at succes
e same plate. It is well known that there

use a special form of colour screen. Experiments showed that if one of the ordinary sensitive plates of patent plate glass was cleared, and a small patch of the gelatine film stained with yellow dye, a bright star photographed through this screen, held in the plate carrier almost in contact with the plate, could be diminished any desired number of magnitudes, and that definition was not sensibly affected anywhere in the field. It is easily shown that the effect of the parallel screen is to alter the focal setting by about one third of the thickness of the screen, while the scale value is unaffected. If the screen is 1·5 mm. thick and separated from the plate by a space of 0·5 mm., a deviation of the normal to the surface of half a minute of arc at the front, or one and a half minutes of arc at the back surface, produces a displacement in the image of 0·0001 mm. It follows that no great accuracy is required in figuring the surface of the screen, and it is probable that one could always find a piece of glass sufficiently good among one's spoiled plates.

The screen which we have used hitherto was made of worked glass by Messrs. Sanger Shepherd & Co., to whom we are much indebted for the interest they have taken in the experiment and the care which they have given to the work. A thin film of gelatine was coated on to the surface and dyed a deep orange; it was then cut down to a patch 3 mm. square. This screen diminished the light of a star about six magnitudes. It was usually quite easy to set for and pick up the selected finding star so that the bright star fell well within the colour patch. When it was desired to photograph a star such as μ *Herculis* inside the patch with its ninth-magnitude companion about 30″ distant outside, the back of the plate carrier was taken off and the instrument set with the screen in place, the stars being viewed with a low-power eyepiece. When we were satisfied that this colour-screen method gave results which looked good, we added a number of bright stars to the programme and adopted the second rule:

II. *All stars brighter than* $6^{m}\cdot 0$ *are to be photographed with a colour screen:* The only serious difficulty with these screens is that they are not permanent. We heard from Messrs. Sanger Shepherd that they had some difficulty in getting the small gelatine patch to adhere to the worked glass surface. They finally succeeded so well that after rather more than twelve months' use the patch, contracting, pulled off the face of the glass. Our series for bright stars were thus interrupted for the time. We realise that it is necessary to devise a form of screen which is permanent, not easily scratched, and which can be cleaned, and experiments are now in progress towards that end.

There is one objection which may be brought against the use of an orange screen to cut down a star's light: that the effective wave-length of the light from the bright star is not the same as that of the light from the comparison stars, and that conse-

quently atmospheric dispersion may produce an exaggerat effect. On the meridian this acts only in the y coordi which we do not generally use (see later). It should be remem that the light which, after passing through the orange scr forms the image of the star is not necessarily of greater effe wave-length than usual, since the orange dye may let thro violet light. Should we adopt the orange dye for the final f of our screen, its absorption spectrum must be examined ph graphically.

§ 4. Let us now consider the various systematic errors wh may be found in the plates, beginning with those of a perman or semi-permanent kind.

The most serious are those included in the category of "h angle error," of which the two principal causes may be: (1) opt distortion varying with the hour-angle, especially when, a Cambridge, a mirror forms part of the optical train; atmospheric dispersion. We realised from the outset that way to ensure freedom from these errors was to work a definite hour-angle for each star; the only question was, Sh we work always on the meridian, or choose in some cases an h circle not very far from it? If we chose the meridian, measured only the x coordinates, any effect of atmospheric (persion must be eliminated; but we should be sacrificing a g deal of parallax factor, and consequently of the weight of determination.

It is not necessary to reproduce here the tables which w constructed to show what was the maximum parallactic (placement in x which could be obtained for any star, on condition that it was photographed upon the meridian at a t when the Sun was at least 10° below the horizon. The wh available displacement in x is $1{\cdot}57\pi$ for a star in 0^h, rise $1{\cdot}93\pi$ for a star in 6^h, falls to $1{\cdot}45\pi$ for a star in 16^h, and is t nearly constant as far as 22^h R.A.

The parallax factors for the limiting morning and even observations under these conditions are usually unequal, and total displacement might be somewhat increased by observing the meridian in a particular hour-angle for each star. I there is a peculiar inconvenience about this procedure. T most favourable dates for observation of all stars between and 21^h R.A. are crowded into a few weeks; and, what is wo all these stars must be observed between 17^h 20^m and 18^h sidereal time. By departing from the meridian to gain a sli formal advantage in parallax factor we make a hopeless block the observing programme. We have therefore adopted the sim working rule:

III. *All photographs must be taken within half an hour of meridian:* It is very convenient to make the working list in form of a card catalogue. Each star has a card on which the pa lactic ellipse is drawn from the tables given by Sir David ((*Annals of the Cape Observatory*, vol. viii.). On the ellipse

marked the places corresponding to the dates up to which evening observations and from which morning observations are possible. A glance at the card shows whether circumstances are favourable or unfavourable; whether the evening observations should be put off to the last moment, or may be made with equal advantage any time in the preceding month; and whether the morning observations must be got immediately after the earliest possible date, or may be delayed without damage. The conditions vary so much from star to star, especially in a latitude like that of Cambridge, which is really too high for convenient parallax work, that to have the diagrams always in sight is really necessary. They are made complete by a tracing from the B.D. chart to identify faint stars, and by the necessary miscellaneous instructions.

§ 5. Errors of the réseau, including "projection errors," scarcely enter into the parallax equations if reasonable care is taken in centering the plate: they affect only the star places.

An error of a semi-permanent kind is tilt of the plate, which displaces the centre of the plate with respect to the edges. It is particularly necessary to guard against such an error accumulating.

§ 6. Perhaps the most important error which is likely to affect all the exposures on one plate systematically, but to vary from plate to plate, is "guiding error." If the clock is not driving correctly, it is probably going pretty regularly either fast or slow, and the stars on the plate are continually trailing a little in one direction and being brought back: under these conditions a bright star image is displaced with reference to a faint by an amount which becomes quite sensible before the distortion of the disc is apparent on inspection. A good electric control will correct errors as soon as they amount to two or three tenths of a second of arc, and possibly the best visual guiding may do the same. The automatic control has this advantage, that one can set the clock regulator so that the accelerating and retarding trains come into operation with nearly equal frequency, which eliminates guiding error, properly so called. A slight continuous trail in one direction has little or no effect on the relative places of the images.

Another "plate error" is local distortion of the gelatine film, too local to be eliminated by the use of the réseau. Discordances appear from time to time which may be attributed with some confidence to this source. The remedy is to separate the different exposures well, and not to take too many on one plate.

§ 7. The plates are measured upon the Cambridge measuring machine (described in *Monthly Notices*, 1901, vol. lxi. p. 441), which has been found to be extremely convenient, accurate, and satisfactory. It has been found to be free from sensible errors of screws, scales, or optical distortion, with the exception of one very small term, which is rigorously eliminated when the plate is measured in two opposite orientations. The accidental error of

on a star-image appears to be very small, so
y to make many settings on a single image.
wo—more if the first two are discordant.
is worth remarking in this connection tha
ot usually appear to have much influence on
measures of a plate, though it may mak

first all images were measured in two opposite
rred to us later that if the error of measure
n orientation was really systematic for imag
ty and appearance, it should be eliminated in
asures of several images of the same star b
them in the direct position only and the oth
d.
mination of the measures of about thirty p
is was the case, and that very little accuracy
st if the labour of measurement had thus b
half. We therefore adopted the rule :
*Measure only two of the four exposures on a
orientation, and the other two in the rever*
ible to economise measurement still more.
ns of our card-catalogue it appears that t
tic displacement for observations on the
nore than half as great in the y coordinate

nces, however, are in practice so small that they cannot sensibly lter the deduced value of the parallax.

So our procedure is :

VI. *Choose any plate, or the mean of any number of plates, as standard, and reduce the others to this :* Since all the neces- ary corrections for any given plate are linear functions of the oordinates it follows that the difference of the measured coordi- ates of the same star on two plates (barring accidental errors nd proper motion) is a linear function of its coordinates on either ne of the plates, or on any other plate of the same field, or ven of the x of one plate and the y of another.

Each of our comparison stars (which as a first approximation re must assume to have no sensible parallax or proper motion) ives us then an equation of condition of the usual form

$$x-\xi=a\xi+b\eta+c$$

here x, y are the coordinates on the plate, and ξ, η the standard oordinates.

These equations might be discussed by least squares to find he plate constants a, b, c. But there is an approximate method, irst proposed by Dyson, which has been found in practice to give bout as good results with much less work. The following are ome results of an investigation by one of us (H. N. R.) which vill appear later.

(1) The least-square and approximate methods give identical alues of the reduction to standard for a star situated at the entre of gravity of the comparison stars (considered as a system f equal particles in a plane). For other points the two methods ive slightly different values, depending upon the differences of he constants a and b.

(2) When the comparison stars are distributed with tolerable ymmetry in the four quarters of the plate, the values of a and b btained by the approximate method differ from the least-square alues by less than the probable errors of the latter.

(3) The weight of the reduction to standard determined by east squares is greatest for the centre of gravity, and falls off vith increasing rapidity as we move away from this point in any lirection. At the average (mean-square) distance of the com- arison stars from the centre the weight is $\frac{1}{3}$ of its maximum alue. If there are n comparison stars the maximum weight of he reduction is n times that of one equation of condition.

It follows from the above that the comparison stars should be o chosen that (a) their centre of gravity falls as near as ossible to the parallax star, and (b) they are as evenly dis- ributed as possible among the four quarters of the plate. If hese conditions are fairly well satisfied, the approximate method f reduction may be used without loss of accuracy. Our experi- nce shows that this can almost always be done in practice.

It should be remembered that in our equations of condition

we have expressed the correction necessary to reduce a plate standard as a function of the standard coordinates. Cons quently when our "parallax star" has a large proper motion, must correct the standard coordinates of this star for th motion before using them to compute the quantity $a\xi+b\eta+$ This correction is only sensible for a few very rapidly movi stars.

§ 10. If accidental errors alone had to be considered, would pay us to use very few comparison stars, and to spend t time saved in measurement upon taking more plates. The er of a *reduced* coordinate of our parallax star consists of tw parts: (*a*) the error of its own measured coordinate, and (*b*) th of the calculated correction to reduce it to standard. Only t latter part, which is the smaller of the two, can be diminish by using more comparison stars. Calculation on this ba shows that it would pay us best to use only four or five com parison stars, and take more plates, even if it took us twice long to take a plate as to measure it.

But to take more plates, with our restrictions and climate, not always possible, and there is an obvious objection to the u of so few comparison stars, for one of them may have a consid able proper motion or parallax much greater than the errors observation.

This will alter the absolute term of one of our equations condition by an amount compared with which the errors of t other equations may be neglected. If we had only three com parison stars, it would still be possible to find values of $a, b,$ which would exactly satisfy the three equations of condition. we had four, consideration of a typical case shows that both t least-square and approximate solution give almost equal residu for the four stars—two positive and two negative—so that cannot pick out the bad one. Something of the same so happens whenever the bad star is alone in the quarter of t plate in which it lies. To enable us to pick out possible cases large proper motion or parallax among our comparison stars must have at least two of them in each quarter of the plate.

In the great majority of fields it is possible to find eig measurable stars, such that their centre of gravity lies within few minutes of arc of the parallax star, while there are two them in each quarter of the plate.

It often helps us to satisfy the last condition if the lin dividing the plate into quarters (*i.e.* those separating the sta which are combined into groups in the approximate method reduction) are inclined to the axes of coordinates.

§ 11. When all the plates of a field have been reduced, t residuals for the parallax star are converted into seconds of ar reduced to a common epoch with the tabular proper motion the star, and discussed by least squares in the ordinary fashio the unknowns being corrections to the star's assumed x coordina and proper motion, and its parallax. It is not worth while

discuss the residuals for the comparison stars by least squares, because, as we have just seen, any parallax or proper motion in one of them will produce systematic changes in the residuals for all the others, so that the results for the different stars are not independent. Approximate values of the proper motions and parallaxes may, however, be very quickly obtained from the means of the residuals for each parallactic epoch. If any comparison star has a large parallax or proper motion the fact will appear by inspection of its residuals. It should then be abandoned as a comparison star, and put on the list of "parallax stars," and the plates be reduced anew with the remaining comparison stars. It is also worth while to measure approximately the y's on one plate of the last epoch, and reduced this to our standard, so that any large proper motion in declination may be detected.

In this way we may assure ourselves that none of our comparison stars has a large parallax. If we assume that the relative parallaxes and proper motions of these stars are really insensible, and that the values we have calculated for them are entirely due to accidental errors, we obtain a superior limit to the probable error of a parallax or proper motion derived from our plates. If the probable errors so obtained agree with those found from the least-square solution for the "parallax star" we may be satisfied that our comparison stars are really remote.

We may then pick out three of them, so that their centre of gravity falls near the "parallax star," measure accurately the y's for these four stars, reduce them to standard, and get from them a new determination of the parallax. This involves much less work than the discussion of the x's, for the reductions may be made very short. We are thus able to utilise the y's without too much work in proportion to their weight.

§ 12. Our solutions give us the difference between the parallax of our principal star and the mean of those of the comparison stars. We know the magnitudes of the latter and superior limits for their proper motions. Now Professor Kapteyn has shown that the mean parallax of a group of stars of known proper motion and magnitude can be predicted with considerable accuracy, so that for eight stars it is decidedly improbable that the actual mean will differ from the computed one by half the amount of the latter. For our comparison stars his formulæ give a mean parallax less than $0''\cdot01$.

As we have already safeguarded ourselves against the exceptional case when one of our comparison stars has a large parallax, we may be satisfied that the uncertainty of their mean parallax will be small, and we may therefore pass from the relative to the absolute parallax of our principal star with some confidence when we desire to use the result for statistical purposes.

§ 13. There remain for consideration the principles that have guided us in forming our first working list.

It has been shown clearly by Kapteyn and Newcomb that the average parallax of stars is so small that if a large list of

stars is selected at random and observed, the spurious paralla
will be far more numerous than the real parallaxes in the list
results: in other words, we are not yet in a position to att
the problem of parallaxes in general. While methods are still
an unsettled state, and while there is little evidence as to
real probable error of a parallax derived by photography,
shall do well to confine our attention to stars of two carefu
selected classes.

A. Stars for which any information as to parallax, even if
be only a superior limit, is valuable—visual binaries, where
parallax gives the mass; variable stars, where the parallax gi
the real range of light variation in terms of the light of the Su
pairs of stars with common proper motion, where the parall
gives the size of the system; star clusters; and nebulæ.

B. Classes of stars which are likely to have larger parall
than the stars in general—bright stars and stars of large prop
motion, especially the latter.

There will naturally be a wide difference of opinion as to t
objects to be included under the first head; the second is in som
respects easier to settle. We have tried to include the mo
promising stars of types I. and III., for which information
scanty. We have also included a number of stars of both class
which have been investigated elsewhere with discrepant results

The observation of a great part of the objects in this first li
is well advanced, and we hope to be able to publish first resul
for the whole within the next year or two. Our experience u
to the present seems to show that one observer who can give h
whole energy to the work may have with advantage about fort
stars on his working list, of which he will miss a few at one epoc
or another owing to spells of bad weather. In this country h
will not accumulate very many more plates than he can measur
to reduce if he imposes on himself the stringent rule of meridia
observation which we have considered essential and adopts th
simplified programme of measurement and reduction which w
have used.

We should like to say in conclusion that we think it ver
desirable that those astronomers who are undertaking determi
nations of stellar parallax should follow the example of the line
of-sight spectroscopists and observe regularly a few stars i
common. Only by some such informal co-operation does it seem
possible to test what is the absolute accuracy of the work. W
should therefore welcome suggestions for additions to our working
list as well as criticism on the methods we have adopted.

First Working List for Stellar Parallax. Cambridge Observatory.

ame.	Position 1900·0. α	δ	Mag.	Sp. Type D.C.	P.M. on Great Circle.	Notes.
	h m	° ′			″	
opeiæ ...	0 3·8	+58 36	2·42	F.	0·55	0″·16 Pritchard ; 0″·10 Flint
bridge 34 ...	0 12·6	+43 27	7·9		2·80	0·29 Auwers ; 0·31 Flint.
opeiæ ...	0 42·9	+57 18	3·64	F.	1·20	Binary ; 7ᵐ comp. dist. 5′ (1900). 0·18 Peter ; 0·44 Davis ; 0·34 Flint.
20 ...	0 43·1	+ 4 46	5·7	H. ?	1·37	0·16 and 0·12 Flint.
opeiæ ...	1 1·6	+54 26	5·21	H.	3·75	0·13 Peter ; 0·24 Bauer ; 0·28 Jacoby ; 0·07 Flint.
opeiæ ...	1 5·0	+54 37	5	A.	0·22	0·23 Jacoby. In same field with μ.
... ...	2 14·3	− 3 26	Var.	M.	0·24	
i	2 58·8	+38 27	Var.	M.	0·18	Irregularly periodic.
i	3 1·7	+40 34	Var.	A.	0·03	Sp. binary. 0·07 Chandler ; 0·04 Chase.
6888, 9 ...	3 40·2	+41 9	9 ; 9·5		1·38	Double ; dist. 9″ ; −0·14 Flint.
... ...	3 55·1	+12 12	Var.	B.	0·02	Algol var. 3·4 to 4·2 ; sp. binary, both comp. bright.
7443 ...	3 56·5	+35 2	8·5		2·19	−0·02 Flint.
9012 ...	4 44·4	+45 41	7·5	A.	0·68	
orum ...	6 8·8	+22 32	Var.	M.	0·07	Var. 3·2 to 4·2. Vis. and sp. binary.
orum ...	6 58·2	+20 43	Var.	H. ?	0·02	Var. 3·7 to 4·5. Sp. binary ; probably triple.
orum ...	7 28·2	+32 6	1·56	A.	0·21	Binary ; both comp. sp. binaries. +0·20 Johnson ; −0·17 Flint.
... ...	8 41·5	+ 6 47	3·5	F.	0·21	Vis. and spect. binary.
Maj. ...	8 52·4	+48 56	3·17	A.	0·50	0·13 Peters ; 0·11 Flint.
Maj. ...	8 54·2	+42 11	4·19	F.	0·51	0·20 Belopolsky ; −0·07 Flint. Common P.M. with ι Ursæ.
ridge 1646	10 21·9	+49 19	6·5	A. ?	0·84	0·11 Kapteyn.
21185 ...	10 51·9	+36 38	6·8		4·75	0·50 Winnecke ; 0·43 Kapteyn ; 0·37 Flint.
21258 ...	11 0·5	+44 2	8·5		4·40	0·26 Auwers ; 0·26 Krüger ; 0·17 Kapteyn ; 0·37 Flint.
Maj. ...	11 12·9	+32 6	4 ; 5	G.	0·74	Vis. binary ; brighter comp. sp. binary.
1677 ...	11 14·8	+66 23	9·0		3·04	0·25 Geelmuyden ; 0·19 Bergstrand. Other stars near suspected of parallax.

Name.	Position 1900·0. α h m	Position 1900·0. δ ° ′	Mag.	Sp. Type D.C.	P.M. on Great Circle. ″	Notes. ″ ″
3₁ Leonis .. 3₂	11 21·7	+ 3 33	6·5 / 7	I.	0·75 / 0·68	
ι Leonis	11 44·0	+15 8	2·07	A.	0·54	0·05 and 0·01 Pritchar
Groombridge 1830	11 47·2	+38 26	6·5	A.?	7·05	0·18 Schlüter; 0·16 Ka −0·01 Flint.
Lalande 22901 ...	12 7·8	+10 36	7·5		0·44	These three stars se form a group. The P almost entirely in southward.
,, 22908 ...	12 8·2	+11 24	7·5		0·59	
,, 22914 ...	12 8·4	+10 36	7		0·30	
γ Virginis .	12 36·6	− 0 54	3·0; 3·2	F.	0·58	Binary. Sp. Type I (McClean).
δ Virginis ...	12 50·6	+ 3 56	3	M.	0·51	
Lalande 25334 ...	13 34·7	+11 15	5·6	A.		0·25 Flint.
A. G. Berlin A. 4999	13 40·2	+18 20	9·2		2·0	
Lalande 25372 ...	13 40·7	+15 20	8·5		2·32	0·43 Flint.
ξ Boötis	14 46·8	+19 31	4·5; 6·5	G.	0·16	Binary.
A. Oe. 14318 ...	15 4·7	−15 59	9·3		3·74	A pair with a rema common P.M.
,, 14320 ...	15 4·7	−15 54	9·2		3·74	
Lalande 27742	15 8·3	+19 39	7·5		0·67	A pair with proper essentially the same
,, 27743	$\Delta\alpha + 0^s{\cdot}31$	$\Delta\delta + 23''{\cdot}3$	8·0		0·62	
OΣ 298	15 32·4	+40 9	7; 7·4		0·50	Visual binary.
Weisse₂ 720 ...	15 32·5	+40 8	7		0·50	Follows proceeding 5½ˢ, 1′ 43″ N. Th pairs have common
Lalande 29381 ...	16 1·5	+39 26	7		0·56	In the same field, bu in different directio
,, 29439 ...	16 2·9	+38 55	8·5		0·60	
ζ Herculis ...	16 37·6	+31 47	3	G.	0·61	Binary, 3 and 6·5; equal. 0·15 Lewis troscopic).
η Herculis ...	16 39·5	+39 7	3·69	K.?	0·08	0·40 Belopolsky; 0·1
W. B. XVII. 322 .	17 20·8	+ 2 14	8·0		1·36	0·17 Flint.
μ₁ Herculis ...	17 42·6	+27 47	4·0	I.?	0·81	A faint companion wi mon P.M. is a 9·4 and 10.
Σ 2398	18 41·7	+59 29	8·2		2·27	Double; 17″; commo 0·35 Lamp; 0·32 I
Munich I. 18180...	18 53·1	+ 5 48	9		1·26	
6 Cygni	19 9·5	+49 40	6·6	H.	0·64	Double; 10″. 0·4 −0·02 Hall.
B.D. +30° 3639...	19 30·9	+30 18	9			Wolf-Rayet star wit gen atmosphere diameter.
Lalande 37647 ...	19 41·8	+33 22	8·5		0·47	Double.
,, 37686 ...	19 42·6	+33 34	5·5		0·47	Common P.M. with l

ame.	Position 1900·0. α		Mag.	Sp. Type D.C.	P.M. on Great Circle	Notes.
	h m	° ′			″	
ni	21 2·4	+38 15	5·11	H.	5·16	0″·36 Wilsing, with suspected periodic motion of 61₁; Davis finds parallax of two stars sensibly different.
lei... ...	21 9·6	+ 9 37	4·5	F.	0·30	Short period binary. 0·02 Flint; 0·02 Leavenworth; 0·07 Hussey (spectroscopic). Necessary to take plates through period of six years to eliminate effect of close binary.
i	21 10·8	+37 36	4; 10	F.	0·48	Binary. 0·08 Beloposky.
43492 ...	22 12·3	+12 24	7	A.?	0·83	
... ...	22 24·5	+57 12	9; 11		0·95	Binary. 3″.
ei	22 25·5	+57 54	Var.	F.?	0·01	Sp. binary.
ei	22 58·9	+27 32	Var.	M.?	0·22	Irregular.
45755 ...	23 16·8	+48 33	7·5	A.	0·68	
omedæ ...	23 32·7	+45 55	4	K.	0·45	Sp. binary.
46650 ...	23 44·0	+ 1 52	8·7		1·4	0·23 Flint.

mbridge Observatory:
1905 *June* 2.

The Parallax of Lalande 21185 *and γ Virginis from Photographs taken at the Cambridge Observatory.* By Henry Norris Russell, Ph.D.

§ 1. The work upon which the writer has been engaged for the past two years as a research assistant of the Carnegie Institution has now progressed far enough to permit the publication of its first results. An outline of the methods employed, with the reasons which led to their adoption, is given in the preceding paper. The present communication deals with the numerical data obtained for the first two stars whose discussion has been completed.

§ 2. *Lalande* 21185.—

R.A. $10^h\ 57^m{\cdot}9$, Dec. 36° 37′ N. (1900·0), Mag. 7·3, P.M. 4″·77.

Previous investigations have shown that this is one of the nearest stars in the northern hemisphere, but they differ among themselves sufficiently to justify a fresh determination of its parallax.

The present discussion is based upon eight plates taken with

the Sheepshanks telescope (the first five by the writer, and the rest by Mr. Hinks), the circumstances being as follows :

No. of Plate.	Date.	Sid. T. h m	Exposures.	No. of Plate	Date.	Sid. T. h m	Exposures.
191	1903 Dec. 9	11 10	4	268	1904 Apr. 25	10 57	4
194	13	11 11	4	397	Dec. 30	11 6	3
258	1904 Apr. 16	11 3	4	405	1905 Jan. 9	10 43	4
260	19	11 10	4	426	Apr. 15	10 56	4

The fourth column gives the number of measurable exposures on each plate, and the third the mean of the times of the middle of these exposures.

The plates are coated on "patent plate" glass, and are of the size used for the astrographic chart, but owing to the longer focal length of the Cambridge telescope the field is a little less than $1\frac{1}{2}°$ square. A standard Gautier réseau is impressed on all plates. The réseau interval of 5 mm. corresponds to $175''\cdot8$.

§ 3. There is a marked absence of stars in the N.E. part of this field, so that it was not possible to secure a perfectly symmetrical distribution of the comparison stars.

The following table shows the stars finally chosen, their B.D. numbers and magnitudes, the magnitudes given in the A.G. Catalogue (Lund) when they appear therein, and the approximate coordinates of the stars upon our plates the plate, centre being (20, 20). A denotes the "parallax star," Lal. 21185.

Star.	B.D.	Magnitude. B.D.	Lund.	*x*.	*y*.
1	+37° 2142	8·3	8·2	9·87	29·37
2	36 2141	8·6	8·5	10·95	19·63
3	37 2145	6·8	7·5	13·04	32·13
4	37 2151	7·7	8·2	16·65	25·18
5	36 2144	9·1	—	17·25	11·87
6	36 2146	8·5	8·5	17·91	11·69
7	36 2150	8·9	8·8	25·99	14·56
8	36 2151	8·8	8·9	26·09	9·87
9	37 2153	8·5	8·4	32·70	32·54
A	36 2147	7·3	7·3	19·85	20·29
Centre of gravity of comparison stars ...			...	18·94	20·76

The centre of gravity falls very near the parallax star, but there is only one comparison star (No. 9) in the north-east quarter of the plate.

§ 4. On the first two plates all images were measured in both orientations, but on the others the first two were measured in the direct position and the last two in the reversed. The measures of individual images are carried to four decimal places (in terms

of a réseau interval), the last place corresponding to estimated tenths of a division of the micrometer head. The means of the coordinates of the four images of each star are then taken, and carried to five decimal places to avoid errors of computation. The differences from this mean are then tabulated for each exposure.

The scale value for the four exposures must be sensibly the same; but the orientation may differ a little, owing to refraction and possible maladjustment of the polar axis of the telescope, and the centering for each exposure is of course different. If there were no accidental errors the differences from the mean should therefore be of the form $\Delta x = by + c$. The deviations from such a formula (which are easily obtained graphically) give a measure of the accuracy of the plate (though they will not show such things as "guiding error," which differs from star to star, but not from exposure to exposure). They also serve as a control of the numerical work, and to detect any errors that may have been made in recording the measures.

The y-coordinates were measured to three decimal places on one plate of each epoch.

§ 5. For the standard coordinates there were chosen the mean of the x's of Plates 191 and 194, with the y's of Plate 191. The approximate method of reduction may safely be applied in this case. It may be worth while to give an example of the method, say the case of Plate 258. Each comparison star gives us one equation of condition of the form

$$a\xi + b\eta + c = x - \xi$$

Taking the mean of the three equations in which ξ is greater than its mean value, and of the six in which it is less, we obtain

$$28{\cdot}262a + 18{\cdot}993b + c = +12531$$
$$14{\cdot}277a + 21{\cdot}646b + c = +11066$$

where the absolute terms are expressed in units of the fifth place. Similarly, from the four equations in which y is greater than its mean value, and the five in which it is less, we obtain

$$18{\cdot}066a + 29{\cdot}806b + c = +\ 9316$$
$$19{\cdot}638a + 13{\cdot}526b + c = +13346$$

From these two pairs of equations we find by subtraction

$$13{\cdot}985a - \ 2{\cdot}653b = +1465$$
$$-\ 1{\cdot}572a + 16{\cdot}280b = -4030$$

whence $\quad a = +58{\cdot}88 \qquad b = -241{\cdot}84$

and from any one of the first four equations

$$c = +15460$$

δx denotes the correction
$\delta\mu$ the correction to Boss
parallax of our star relati
while the absolute terms
arc.

$1{\cdot}000\delta x$	$-0{\cdot}061$
$1{\cdot}000$	$-0{\cdot}051$
$1{\cdot}000$	$+0{\cdot}291$
$1{\cdot}000$	$+0{\cdot}299$
$1{\cdot}000$	$+0{\cdot}315$
$1{\cdot}000$	$+0{\cdot}999$
$1{\cdot}000$	$+1{\cdot}026$
$1{\cdot}000$	$+1{\cdot}288$

The influence of the
absolute terms.

Our normal equations

$8{\cdot}000\delta x$	$+4{\cdot}$
$4{\cdot}106$	$+3{\cdot}$
$0{\cdot}698$	$+0{\cdot}$

whence

$$\delta x =$$
$$\delta\mu =$$
$$\pi =$$

The residuals left on su

We have thus for the definitive result of the measures in x

$$\pi = +0''\cdot346 \pm 0''\cdot015$$

and for the probable error of one equation, *i.e.* of a coordinate derived from one plate, $\pm 0''\cdot031$.

§ 7. We may now investigate the parallaxes and proper motions of our comparison stars. In this case we are justified in an approximate but much shorter form of solution. If $\Delta_1 \ldots \Delta_8$ denote the absolute terms in the successive equations of condition for any star, we easily find by combining the equations in which the factors of π have the same sign

$$1\cdot000\delta x + 0\cdot548\delta\mu - 0\cdot665\pi = \tfrac{1}{4}(\Delta_3 + \Delta_4 + \Delta_5 + \Delta_8)$$
$$1\cdot000\delta x + 0\cdot548\delta\mu + 0\cdot831\pi = 0\cdot217(\Delta_1 + \Delta_2) + 0\cdot283(\Delta_6 + \Delta_7)$$

whence we obtain by subtracting and then dividing by 1·496

$$\pi = +0\cdot145(\Delta_1 + \Delta_2) + 0\cdot189(\Delta_6 + \Delta_7) - 0\cdot167(\Delta_3 + \Delta_4 + \Delta_5 + \Delta_8)$$

Similarly by constructing two equations in which the coefficients of δx and π are the same, but those of $\delta\mu$ widely different, we find

$$\delta\mu = 0\cdot325(\Delta_6 + \Delta_7 + \Delta_8) - 0\cdot306(\Delta_1 + \Delta_2) - 0\cdot123(\Delta_3 + \Delta_4 + \Delta_5)$$

Applying these formulæ as a test to our parallax star, we find $\delta\mu = -5$, $\pi = +343$, in very good agreement with the least-square solution.

For our comparison stars we find in the same way, in thousandths of a second—

Star.	1.	2.	3.	4.	5.	6.	7.	8.	9.
μ	+21	+84	−26	−42	−9	−23	+9	−58	+48
π	−32	+18	0	−5	+7	+7	−19	−18	+35

The sum of all the proper motions or of all the parallaxes vanishes, as it ought to do, since they are all relative to the mean of the group.

If we assume that these values are wholly spurious, and due to errors of observation, we find for the probable errors of a proper motion or parallax for one comparison star the values ± 30 and ± 14 respectively. Comparing these with the values for the parallax star we see that the values of π are completely accounted for by accidental errors (supposing these to be the same for the comparison stars and parallax star), while those of μ are a little larger than the accidental errors would lead us to expect. The large value for star 2 may perhaps be real.

If we assume that our comparison stars have no parallax or proper motion (or, rather, that they all have the *same*), the differences of the residuals on different plates will be due to errors of observation. In this way we obtain for the probable error of a coordinate derived from one plate values which

range from $\pm 0''\cdot 018$ to $\pm 0''\cdot 046$ for the different stars, th mean value being $\pm 0''\cdot 030$. As this has been derived fro residuals left after the reduction of the plates to standard, i which we had to determine three unknowns from eigh equations, we must multiply it by $\sqrt{\frac{8}{5}}$ in order to obtain number comparable with the one previously found for th parallax star. We thus obtain $\pm 0''\cdot 038$ for the true probabl error of an x-coordinate of a comparison star derived from on plate. This is somewhat larger than the value for the paralla star, perhaps because the comparison stars really have sma proper motions of their own.

It is of interest to compare the agreement of the plates wit one another with that of the different exposures on one plat which can be found from the differences mentioned in § 4.

The average value (without regard to sign) of these discord ances for all the stars measured on the eight plates is 3·12 unit of the fourth place, or $0''\cdot 055$. To find the correspondin probable error of a single image we must multiply by th constant 0·845, and also by $\sqrt{\frac{4}{3}}$, since we are considerin deviations from the mean of four quantities, and $\sqrt{\frac{10}{8}}$ becaus we have tried to represent ten quantities for each exposure b a formula with two constants. This gives for the probabl error of one image $\pm 0''\cdot 060$. That of the mean of four image would then be $\pm 0''\cdot 030$, which is close to that found from th agreement of different plates. We may therefore conclude tha for these plates the "plate errors" are very small.

The reduction of the approximate values of y for the fou epochs gives residuals for the comparison stars that lie withi the errors of the measures, showing that their proper motions i declination, like those in R.A., are all small.

§ 8. We pass now to the discussion of the y's. For thi purpose three of the comparison stars were chosen—Nos. 2, 6 and 9—whose centre of gravity falls within one réseau-interval o the parallax star, and whose parallaxes all appear to be very small The y's of these four stars were measured accurately on all th plates. The reduction to standard is in this case very simple If ξ_2, η_2 denote the standard coordinates of star 2, and so on, we determine three auxiliary constants, α, β, γ, by the equations

$$\alpha\xi_2+\beta\xi_6+\gamma\xi_9=\xi_A$$
$$\alpha\eta_2+\beta\eta_6+\gamma\eta_9=\eta_A$$
$$\alpha+\beta+\gamma=1$$

Then if we denote any expression of the form $a\xi+b\eta+c$ by f, we will have

$$f_A=\alpha f_2+\beta f_6+\gamma f_9$$

The correction to reduce the place of the parallax star to standard may thus be derived immediately from the differences from standard for the three comparison stars.

The results obtained in this case are interesting as showing how conspicuous a large proper motion is, even on photographs taken at short intervals. In the table below the first line gives the residuals in thousandths of a second of arc; the second, the correction necessary to reduce them to 1904·0 with Bossert's proper motion, $-4''\cdot74$; and the third, the corrected values:

Plate ...	191	194	258	260	268	397	405	426
Residual...	+ 33	− 33	−1419	−1436	−1486	−4984	−5102	−6035
Correction	−289	−242	+1379	+1417	+1493	+4735	+4863	+6105
Corrected value	−256	−275	− 40	− 19	+ 7	− 249	− 239	+ 70

Our equations of condition are:

					O−C.
$1{\cdot}000\delta y$	$-0{\cdot}061\delta\mu$	$-0{\cdot}294\pi$	=	−256	+40
1·000	−0·051	−0·256	=	−275	+ 9
1·000	+0·291	+0·595	=	− 40	−41
1·000	+0·299	+0·588	=	− 19	−18
1·000	+0·315	+0·571	=	+ 7	+13
1·000	+0·999	−0·078	=	−249	−24
1·000	+1·026	+0·027	=	−239	−49
1·000	+1·288	+0·596	=	+ 70	+70

The influence of the parallax is again conspicuous.

The normal equations are:

$$
\begin{array}{llll}
+8{\cdot}000\delta y & +4{\cdot}106\delta\mu & +1{\cdot}749\pi & = -1001 \\
+4{\cdot}106 & +3{\cdot}989 & +1{\cdot}277 & = -\ 389 \\
+1{\cdot}749 & +1{\cdot}277 & +1{\cdot}540 & = +\ 169
\end{array}
$$

Whence we find

	Weight.
$\delta y = -197{\cdot}8$	3·61
$\delta\mu = -\ \ 1{\cdot}5$	1·76
$\pi = +335{\cdot}5$	1·08

The residuals in the equations of condition are given above. From them we derive:

Probable error of δy	± 17
$\delta\mu$	± 25
π	± 31
One equation	± 33

The definition solution from the y's gives therefore

$$\pi = +0''\cdot335 \pm 0''\cdot031$$

The probable error of a y-coordinate derived from one plate is almost exactly the same as that of an x-coordinate, but the latter gives a determination of the parallax with four times as much weight as the former. The agreement of the two values is very satisfactory. Combining them with regard to these probable errors, we have for our final value, relative to the nine comparison stars—

Parallax of Lalande 21185 = $0''{\cdot}344 \pm 0''{\cdot}013$

§ 9. The following table gives in summary form the result of previous investigations of this star's parallax :

Observer.	Date.	Method.	Number of Comp. Stars.	Number of Obs.	Result.
(1) Winnecke	... 1857–58	Heliometer	2	12	$+0''{\cdot}511 \pm 0''{\cdot}01$
(2) Kapteyn	... 1885–87	Transits	2	46–47	$+0{\cdot}434 \pm 0{\cdot}02$
(3) Flint ...	... 1893–95	Transits	2	18	$+0{\cdot}36 \pm 0{\cdot}04$
		or, including a systematic correction,			$+0{\cdot}37$

References: (1) *A.N.* 1147. (2) *A.N.* 2935. (3) *Publications of the Washburn Observatory*, vol. xi. pp. 219, 437.

The present investigation supports the most recent ones in showing that the parallax is smaller than at first supposed, so that this star is not the nearest in the heavens after *a Centauri*, but is more remote than *Sirius*, and probably 61 *Cygni* as well.

§ 10. We have still to consider the effect of atmospheric dispersion on our results. The displacement of a star-image on the plate by refraction is given by the equations

$$\Delta x = \beta X + \text{small terms}$$
$$\Delta y = \beta Y + \text{small terms}$$

where β is the constant of refraction, and X, Y the coordinates of the zenith projected on the plane of the plate, expressed in terms of the focal length as unit.

If the effective mean wave-length of the light of the parallax star differs from that of the comparison stars, the refraction constant will also differ, say by $d\beta$, and the parallax star will be displaced on the plate relatively to the others by $Xd\beta$ and $Yd\beta$ in the two coordinates.

For plates taken near the meridian we have (neglecting terms involving the cube of the hour-angle)

$$X = \frac{t \cos \phi}{\cos (\phi - \delta)}, \quad Y = \tan (\phi - \delta) + \tfrac{1}{4} t^2 \sin 2\phi \sec^2 (\phi - \delta)$$

where ϕ is the observer's latitude, δ the declination of the plate centre, and t the hour-angle expressed in circular measure. The dispersion in x is therefore proportional to the hour-angle, and vanishes at the meridian, while that in y is practically constant for each field.

Computing thus the effect of refraction for each of our plates, and introducing the results into our equations of condition and normal equations, we find for the effect on our unknowns :

Measures in x.	Measures in y.
$d\delta x = +0{\cdot}028 d\beta$	$d\delta y = +0{\cdot}280 d\beta$
$d\delta\mu = -0{\cdot}034 d\beta$	$d\delta\mu = +0{\cdot}000 d\beta$
$d\pi = +0{\cdot}002 d\beta$	$d\pi = +0{\cdot}000 d\beta$

Here $d\beta$ denotes the change in the refraction constant expressed in seconds of arc. As the whole difference between the refraction constants for the visual and photographic rays is less than 1″, it is clear that our results must be free from any sensible error arising from this source, except as regards δy, whose exact value is quite immaterial.

It should, however, be noticed that we have been regarding $d\beta$ as constant, whereas it really varies with the meteorological conditions proportionately to the total refraction. This cannot affect our x-equations, where the coefficients of $d\beta$ are all very small ; but as the change is a seasonal one it may produce some effect on the value of the parallax derived from the y's. The refraction averages greater in winter than in summer ; for our star Y is positive ; therefore the star will appear farther north in winter than in summer, if $d\beta$ is positive. But the effect of annual parallax is to displace a star to the southward in winter and northward in summer.

Consequently if $\delta\beta$ is positive—that is, if the star is bluer than the comparison stars—the effect of seasonal variations in the dispersion will be to make the value of the parallax found from the y's too small. This effect is, however, a small quantity of the second order, and is probably quite insensible.

§ 11. We have finally to consider what is the probable parallax of our comparison stars. We have already found that their relative proper motions and parallaxes are very small. The very small values of the corrections found to the catalogued motion of the parallax star, which is very well determined, show that our comparison stars have no common drift. Their proper motions as computed from our plates are probably largely due to accidental error. If we assume that the true motions and the errors of observation contribute equally to the observed results, the observed proper motions in one coordinate will on the average be equal to the true proper motions in the plane of reference.

We may then apply Professor Kapteyn's formulæ for the mean parallax of a group of stars of given proper motion and magnitude given in No. 8 of the Publications of the Astronomical Laboratory of Groningen. The average magnitude of our comparison stars is 8·3, and their average observed proper motion in x, without regard to sign, is 0″·036. With these arguments

Kapteyn's table [*loc. cit.* p. 31, Table G, headed "All the Stars" gives mean parallax = 0″·0071.

If we discard all hypotheses concerning the proper motion and use the magnitude alone as the criterion of distance Kapteyn's Table C [*loc. cit.* p. 28] gives mean parallax 0″·0074.

We may therefore assume with some confidence for our comparison stars

Mean Parallax = 0″·007

From Kapteyn's researches it appears that it is more likely than not that the parallax of a single star will be within 50 per cent. of the value given by his table for a star of its magnitude and proper motion. For the mean of nine stars we should have a much closer agreement, so that the value just found is not likely to be in error by more than a very few thousandths of a second, especially as we have already seen that none of the stars has a large parallax.

By adding this to the value already found for the parallax of *Lalande* 21185 relative to the comparison stars, we may obtain a very close approximation to its absolute parallax, and this should be used rather than the relative parallax in computing the star's distance, light, and the like.

§ 12. *γ Virginis* R.A. $12^h\ 36^m·3$. Dec. 0° 55′ S. (1900·0) Binary. Components equal: joint magnitude 2·91. P.M. 0″·57 Pos. 327°. Dist. 5″·7 (1904).

This bright star was photographed through the colour screen and eight plates at three epochs were secured before the failure of the latter.

Except on very unsteady nights the images of the two components are well separated; but to ensure this the exposures had to be short, and, as the field is a very poor one, it was found impossible to get the ordinary number of measurable comparison stars. If we had had a series of colour screens of varying densities this could have been remedied by using a denser screen and longer exposures; but, as things were, it was necessary to get along with only six comparison stars—the smallest number for any of our fields. It also appeared early in the course of measurement that these plates were below the average in quality, owing perhaps to the relatively low altitude of the star, which is one of the southernmost on our list. One of the plates was shown by the discordance of the four exposures to be particularly bad, and it was given half weight, a decision confirmed later by the large residuals which it gave in the final solutions.

The present discussion may therefore be taken as an example of our photographs at their worst, and it is gratifying to find that even then they give results of some apparent value.

The general plan of the work was exactly similar to that for the previous star, so that only the points of difference need be mentioned here.

§ 13. Having only six comparison stars the method of reduction was somewhat altered. The stars were divided into three pairs, and the means of the equations of condition for each pair were taken, thus giving three equations for the three plate constants. As the centre of gravity of the six stars fell within a réseau interval of the parallax stars, the use of this approximate method is justifiable.

Solutions were made for the two components separately, the parallaxes of the comparison stars were approximately determined, three of them were chosen and the y's measured, with the results given below. A denotes the southern and B the northern component of the binary, and the assumed proper motions are $-0^s{\cdot}038$ ($= -0''{\cdot}57$) in x and $+0''{\cdot}015$ in y.

From measures in x.

	Star A.	Star B.	Weight.
$\delta x =$	$-0''{\cdot}029 \pm 0''{\cdot}030$	$-0''{\cdot}019 \pm 0''{\cdot}038$	2·66
$\delta\mu =$	$+0{\cdot}110 \pm 0{\cdot}046$	$+0{\cdot}089 \pm 0{\cdot}059$	1·14
$\pi =$	$+0{\cdot}072 \pm 0{\cdot}027$	$+0{\cdot}054 \pm 0{\cdot}034$	3·34
Probable error of unit weight	$\pm 0{\cdot}049$	$\pm 0{\cdot}063$	

From measures in y.

	Star A.	Star B.	Weight.
$\delta y =$	$+0''{\cdot}028 \pm 0''{\cdot}037$	$+0''{\cdot}026 \pm 0''{\cdot}079$	2·64
$\delta\mu =$	$-0{\cdot}088 \pm 0{\cdot}057$	$-0{\cdot}107 \pm 0{\cdot}121$	1·12
$\pi =$	$+0{\cdot}070 \pm 0{\cdot}074$	$+0{\cdot}068 \pm 0{\cdot}157$	0·67
Probable error of unit weight	$\pm 0{\cdot}061$	$\pm 0{\cdot}128$	

The weight of the parallax derived from the y's is but one fifth of that from the x's (and even this is more than it would be for the average star). It would not ordinarily pay to measure them; but as the present series cannot be continued, it seemed worth while to get all possible information out of the plates.

The large probable errors found for the y coordinates of star B are due to one very large residual for the plate which had previously, for quite other reasons, been given half-weight.

If we combine the results from the x's and y's with regard to their probable errors, we have

Parallax of	A	$+0''{\cdot}072 \pm 0''{\cdot}024$
	B	$+0{\cdot}054 \pm 0{\cdot}033$

The two values agree within their probable errors. Taking the mean with equal weights, we have for the parallax of γ *Virginis* relative to the six comparison stars

$$\pi = +0''{\cdot}063 \pm 0''{\cdot}022$$

There is, however, something unsatisfactory about this solution. The proper motion of γ *Virginis* (which is in the Fundamental Catalogue) is very well determined, and the large corrections found above are almost certainly not real. It is indeed barely possible that the comparison stars have a "group motion" which accounts for the discrepancy; but this is exceedingly improbable, and the large probable errors of the calculated values of $\delta\mu$ suggest that these values themselves are due to errors of observation. It therefore seemed advisable to repeat the least square solutions, rejecting the terms in $\delta\mu$. The results were

From measures in x.

	Star A.	Star B.
$\delta x =$	$+0''.025 \pm 0''.023$	$+0''.024 \pm 0''.026$
$\pi =$	$+0.094 \pm 0.029$	$+0.072 \pm 0.032$
Probable error of unit weight	± 0.056	± 0.063

From measures in y.

	Star A.	Star B.
$\delta y =$	$-0''.018 \pm 0''.023$	$-0''.028 \pm 0''.047$
$\pi =$	$+0.106 \pm 0.070$	$+0.117 \pm 0.139$
Probable error of unit weight	± 0.061	± 0.122

The representation of the observations is about as good as before, so that the idea that the large values of $\delta\mu$ are due to accidental error is confirmed. Combining these new values of the parallax with regard to their probable errors we have

Parallax of A	$+0''.096 \pm 0''.027$
B	$+0.074 \pm 0.031$

and for the mean of the two, with equal weights,

$$\pi = +0''.085 \pm 0''.021$$

This result differs from the one previously found by less than the probable error of either one. In the absence of certainty which of the two solutions is to be preferred we may perhaps best take the mean of the two, which gives

$$\textbf{Parallax of } \gamma \textbf{ Virginis} = +0''.074 \pm 0''.022$$

as the best value, relative to the mean of the six comparison stars, which can be derived from our plates.

§ 14. The approximate discussion of the residuals for the comparison stars gives values for their parallaxes and proper

ıotions whose means (without regard to sign) are $0''.037$ and $''.051$ respectively. These values appear to be due to errors of bservation. If we assume that the comparison stars have no ensible parallax or proper motion, the probable error of a ıeasured coordinate for one of them derived from one plate omes out $\pm 0''.080$. This is larger than the value previously ound for the parallax star, so that it would appear that in this ase the images taken through the gelatine patch of our colour-creen are better than those taken through the clear glass utside.

The probable error of a single image deduced from the comıarison of the exposures on each plate with one another is $\pm 0''.084$, which would lead us to expect a probable error of $\pm 0''.042$ for a plate with four exposures. This is much less han the value given by comparison of different plates, so that it eems that in this series there is some sort of "plate error" hich is nearly the same for all the images of one star on a late.

Calculation of the effect of atmosphere dispersion on our esults gives the following (when the seasonal variations of $d\beta$ re disregarded):

Results from x.	Results from y.
$d\pi = -0.005 d\beta$	$d\pi = +0.004 d\beta$

o that we need fear no error from this source.

The average magnitude of our comparison stars is 8.9, correponding to which Kapteyn gives the mean parallax $0''.006$.

§ 15. The only previous determination of the parallax of *Virginis* known to the writer is a spectroscopic one by Belopolsky. He finds (*A.N.* 3510) that the relative velocity of he two components is 0.278 geographical miles per second, vith a probable error of about ± 0.1 g.m. With Doberck's lements of 1881 this gives $\pi = 0''.051$. Owing to the uncerainty of the inclination of the orbit of the binary (given by lifferent computers as from 31° to 37°) and that of the observed adial velocities of the two stars the probable error of the above alue must be considerable. The agreement with the results of he present investigation is as good as there is any reason to xpect.

§ 16. We may conclude by deriving from our parallaxes such nformation as we can get concerning the brightness, mass, &c. of he stars. In dealing with the brightness of stars the writer vould suggest that Professor Kapteyn's conception of the "absoute magnitude" of a star should be generally used. By the bsolute magnitude of a star Professor Kapteyn denotes the nagnitude which it would appear to have at such a distance that ts parallax was $0''.1$. If m is the star's observed magnitude nd π its parallax, we have then for the absolute magnitude m_0

$$m_0 = m + 5 - 5 \log \pi$$

In calculating this and similar quantities the relative parall already found for our stars should be corrected by adding tl probable mean parallax of the comparison stars.

We thus obtain for Lalande 21185 $\pi = +0''\cdot351$ which, wi the magnitude 7·3 and proper motion 4·77, gives

Absolute magnitude 10·0

The Sun's absolute magnitude is given by Kapteyn as 5·5, that the star is 4·5 magnitudes fainter than the Sun, and giv about $\frac{1}{60}$ as much light.

The velocity of the star at right angles to the line of sight 65 kilometres per second, with a probable error (so far as t present determination of the parallax is concerned) of about 3 k

For *γ Virginis* we find the absolute magnitude of the tv stars taken together to be 2·4. The two components are equal brightness, so that the absolute magnitude of each one of the is 3·2; that is, each of them gives about nine times as much lig as the Sun. The velocity of the system at right angles to the li of sight is 34 km. per second, while from Belopolsky's observ tions the velocity in the line of sight is 21 km., and the star approaching us. This would make the velocity of the system space 40 km. per second in a direction inclined about 60° to tl line of sight. These values are, however, somewhat uncertain.

Using See's elements for the binary system ($a=3''\cdot99$, P=1 years, e=0·90) we find

Major axis of orbit	= 50	astronomical units
Distance of stars at periastron	5	"
" at apastron	95	"
Mass of system	3·3	

Auwers and Lewis have found that the masses of the tv components are nearly equal, and so each of them must be abo 1·6 times as massive as the Sun, whereas they each give abo nine times as much light.

These stars must therefore be either less dense than the Su or have a greater surface brightness, which accords well with tl fact that their spectra are of the first type.

§ 17. In conclusion I wish to express my hearty thanks to tl Director and staff of the Cambridge Observatory for the use its instruments and of all its privileges, and for their cordi interest in the work; and in particular to Mr. A. R. Hinks f much valuable comment and criticism, and especially for takir a large number of plates for me while I was disabled by a lor illness.

Cambridge Observatory: 1905 *June* 9.

The Great Cluster in Hercules. By W. E. Plummer, M.A.

Some time since I received from Professor G. Hale, the late Director of the Yerkes Observatory, a photograph of the cluster in *Hercules*, taken with the large refractor. This plate is labelled: "Messier 13, photographed with the 40-inch Yerkes refractor, August 15, 1900. Exposure four hours, $8^h\ 30^m$–$12^h\ 30^m$ Central Standard Time, with double-slide plate-holder, yellow screen, isochromatic plate. (Signed) G. W. Ritchey." Having recently measured this plate, it seemed desirable to compare the results with what earlier measures existed, and to trace, if possible, any change in the relative coordinates of the stars forming the group. Such an inquiry is no doubt premature, but it might serve to show whether ten or a hundred years were needed in order to conduct such investigations with success.

At the time of the arrival of the plate I had no suitable measuring machine, but Professor Turner kindly placed at my disposal one that had been used at Oxford in the measurement of the plates of the International Chart. The American plate is of the ordinary quarter-plate size and without any réseau lines; while the Oxford machine, without a special adaptor, is only available for plates of the size of those recommended for the International Chart, and the method of measurement requires the employment of a réseau. It was therefore necessary to transfer the American negative to a plate of convenient size and marked with the réseau. For this service I was again indebted to the Oxford Observatory. The copy appears to have been very successfully effected. It might have been anticipated that in the two transfers necessary to produce a fresh negative many images of the fainter stars would be lost; but this is not so. In the case of the faintest stars visible on the original negative, I could generally trace them on the copy by the aid of allineation, and in only a few cases was the image too faint for measurement.

This transferred negative has been measured in two reversed positions of the plate, and with the scales and method of measurement employed the greatest accuracy attainable is the thousandth part of the distance between two réseau lines. Owing to the great focal length of the Yerkes refractor, the angle subtended between two of these lines is approximately $53''$, so that practically the measures have been made to $\frac{1}{20}''$. The diameters of the images were also measured, to determine the magnitude of the stars; but, as will be seen in the sequel, this portion of the work is not so satisfactory as could have been wished. The total number of objects measured is 2131, distributed over an area of eleven minutes square. The law of distribution throughout this area will be considered later.

To reduce the measurements to standard coordinates a certain number of fiducial stars is necessary, and within the small area

of the American negative, meridian places of these do not e[x]
It was therefore necessary to connect the Yerkes plate with [a]
embracing a larger area. This plate was taken by Mr. H.
Plummer and is discussed in the *Monthly Notices* of 1[...]
November. The reductions of the measures have been ba[sed]
upon the positions of the stars there given. Of the seventy s[tars]
whose places are recorded some sixty-two are common to b[oth]
plates; but in a few instances the stars selected at Oxford [for]
measurement were found to have a companion so close that [the]
two images would, from the shorter focal length, natur[ally]
coalesce, and the centre of the combined image would not co[rre]spond to the centre of either, or necessarily to the mean of [the]
two. On this ground seven stars were excluded from the co[m]parison; and this process of rejection, for the reasons mention[ed]
might have been carried further with advantage. An inqui[ry]
conducted in the usual way, showed that the Liverpool [...]
measures could be connected with the Oxford (O) by mean[s of]
the formulæ

$$x_0 = +0.89584x_L + 0.00061y_L - 8.0234$$
$$y_0 = -0.00033x_L + 0.89556y_L - 14.9226$$

Besides these Oxford measures, differential coordinates of [a]
number of stars have also been given by Professor Scheiner, in [his]
paper entitled "Der grosse Sternhaufen im Hercules Messier [13]
nach Aufnahmen am Potsdamer photographischen Refracto[r]"
(*Abhandlungen Königl. Preuss. Akad. der Wissenschaften* [zu]
Berlin, 1892). The places given in this paper are referred to [a]
star, approximately in the centre of the group, whose coordinat[es]
for 1891·0 are quoted as

$$\alpha = 16^h\ 37^m\ 46^s.85 \qquad \delta = +36^h\ 40^m\ 22^s.9$$

This position, reduced to 1900·0, differs from the assumed centr[e]
of the Oxford plate by (P—O)

$$x = +1'\ 13''.58$$
$$y = -\ \ 40.40$$

For the purposes of comparison these constants have bee[n]
applied to the Potsdam measures, together with the smal[l]
differential corrections due to precession, in order to refer th[e]
measures to the equinox 1900·0. This was certainly not th[e]
best method of comparing the different sets of measures; but a[s]
it was the course that was actually pursued the results are se[t]
down here, as they show both the character of the agreement
that may be expected between the measures and the necessity
of adopting a more legitimate and accurate method of com-
parison:—

TABLE I.

Comparison of Measures of Potsdam, Oxford, and Liverpool.

Potsdam No.	Liverpool x 1900.	L−P.	Oxford No.	L−O.	Liverpool y 1900.	L−P.	L−O.
	′ ″	″		″	′ ″	″	″
7	−3 55·27	−0·26	7	−0·07	+4 52·68	−0·37	0·00
9	−3 52·57	+0·25	8	−0·13	−5 13·56	−0·58	−0·54
10	−3 48·71	−0·09	9	−0·05	+ 55·05	+0·04	+0·63
14	−3 29·89	+0·14	11	−1·45	−2 41·83	−0·70	−0·19
27	−2 57·83	+1·54	13	+0·61	−1 53·97	−0·13	+0·45
29	−2 56·45	+0·17	14	+0·19	−3 52·07	−0·78	−0·17
30	−2 54·16	+0·24	15	+1·40	+2 35·55	−0·80	+0·09
34	−2 39·68	−0·02	16	−0·5	− 31·65	−0·04	+0·39
47	−2 7·84	+0·03	17	−0·82	+1 46·49	−0·56	+0·89
48	−2 4·29	+0·44	18	+0·09	−3 0·13	−0·45	−0·13
51	−1 57·43	+0·51	19	−0·01	−2 45·87	−0·46	−0·69
56	−1 38·20	+0·63	21	+0·92	−5 41·34	−0·80	−0·66
63	−1 26·50	+0·06	22	−0·34	− 31·82	−1·58	−0·62
68	−1 19·91	−0·19	23	+0·85	+5 25·84	−0·42	+0·52
72	−1 15·25	+0·28	24	+0·71	−3 3·81	−0·47	−0·21
92	− 51·78	+0·05	25	+0·18	+3 24·73	−0·12	+0·73
103	− 43·70	+0·08	26	+0·22	+1 11·58	−0·90	+0·12
109	− 39·85	+0·20	27	−0·01	−2 33·00	−0·43	−0·18
127	− 26·87	+0·10	28	−0·35	− 1·90	−0·53	+0·20
129	− 23·54	+0·19	29	+0·34	− 57·21	−0·80	−0·21
130	− 23·04	+0·39	30	−0·48	−3 49·30	−0·16	+0·32
148	− 8·16	+0·47	31	−0·54	−2 24·22	−0·30	+0·44
216	+ 19·76	+0·14	32	−0·16	− 43·74	−0·44	−0·12
227	+ 22·55	+0·32	33	−0·07	−3 21·97	−0·18	+0·35
234	+ 28·27	+0·13	34	−0·05	+2 19·72	+0·03	+0·76
287	+ 49·05	+0·08	35	+0·27	− 2·71	−0·63	−0·49
288	+ 50·10	+0·55	36	+0·06	−5 52·50	−0·05	−0·24
296	+ 52·11	+0·29	37	−0·09	−2 54·67	−0·31	−0·07
418	+1 23·44	+0·74	38	−0·08	+ 16·72	−0·68	+0·88
479	+1 40·43	+0·70	40	+0·59	−2 4·87	−0·12	+0·05
507	+1 49·42	+0·81	41	+0·76	−2 6·97	−0·96	−0·73
529	+1 53·87	+0·35	42	−0·37	−5 59·43	+0·02	+0·39
594	+2 15·02	+0·01	43	−0·94	+2 33·56	−0·07	+0·02
603	+2 16·48	+0·03	44	−0·20	+1 37·46	−0·51	−0·28
602	+2 16·58	+0·15	45	−0·46	+1 24·89	−0·52	−0·07
642	+2 32·71	+0·03	46	−0·29	−2 36·24	−0·09	+0·18

Potsdam No.	Liverpool x 1900.	L–P.	Oxford No.	L–O.	Liverpool y 1900.	L–P.	L–O.
	′ ″	″		″	′ ″	″	″
654	+2 39·46	+0·23	47	+0·22	− 5·59	−0·55	−0·1
726	+3 11·37	+0·45	48	+0·21	−4 18·48	+0·08	−0·1
727	+3 11·88	+0·44	49	+0·12	−4 52·52	−0·15	+0·
731	+3 14·03	+0·34	50	+0·35	+1 8·72	−0·70	+0·
739	+3 21·11	+0·24	51	−0·01	+4 43·74	−0·90	−0·
749	+3 34·33	+0·20	53	+0·01	−2 5·58	−0·19	+0·
748	+3 34·15	+0·81	54	−0·41	−5 54·40	−0·45	+0·
771	+4 5·18	+0·50	55	−0·34	−1 12·02	−0·54	+0·
774	+4 14·24	+1·37	56	+0·56	+ 26·78	+1·37	+0·
778	+4 18·76	+0·06	57	−0·14	+4 51·56	−0·51	−0·
781	+4 30·94	+0·52	58	+0·70	+1 27·40	−0·56	−0·
785	+4 36·99	+0·33	59	−0·21	−3 13·61	−0·63	+0·0
786	+4 37·78	−0·04	60	−0·38	+5 19·78	−0·29	−0·1
795	+5 2·93	+0·20	61	+0·23	− 49·26	−0·44	−0·1
799	+5 18·38	+0·58	62	−0·10	−5 1·65	−0·11	−0·4
805	+5 37·44	+0·25	63	0·00	+3 13·11	−0·63	−0·5
815	+6 44·10	+0·14	64	+0·78	+1 0·21	−0·49	+0·0
821	+7 6·50	+1·05	65	−0·10	−6 10·61	−0·37	−0·

Note.—Star No. 30 Potsdam has another star with which it might coalesc No. 60 is ill-formed on the Yerkes plate, and has not been used in derivin the plate constants. No. 418 is described by Scheiner as "neblig." It has small star quite close. No. 748 has the same note, and is similarly circum stanced. No. 774 is marked "Duplex oder nebelknoten." This is an instru tive case. There is another star distant 1″·36 in x and 2″·69 in y. Neith star agrees very well with the Potsdam place, but the mean of the two woul be satisfactory.

The few changes of sign in the residuals (L−P) disclose systematic difference between the two sets of measures, while th uniformity in the amount offers little hope of tracing any effect of motion among the stars. The larger part of the discrepanci may be removed by a slight alteration in the assumed mean dis tance between the origin of coordinates on the Liverpool (o Oxford) and Potsdam plates. The mean difference betwee Liverpool and Potsdam, as determined from these fifty-fou stars, is (L−P)

$$x \quad \dots \quad \dots \quad +0''\!\cdot\!32$$
$$y \quad \dots \quad \dots \quad -0\cdot41$$

It is not difficult to suggest various ways in which thi difference might arise ; but that it is a real difference and doe not arise from the use of the outlying and brighter stars of th group is shown by a more extended comparison between the star that have been measured at Potsdam and Liverpool. I propose

to compare the whole of the Potsdam measures with those derived from the Yerkes plate, but in the denser part of the cluster it has not always been possible to identify with certainty the star that has been measured by Professor Scheiner; and, in addition to these instances of defective identification, some other stars have been rejected because they are accompanied by a bad note implying uncertainty in the original measures. The total number of stars between which it seemed safe to institute comparisons is 560, and the general result is shown in Table II., where a zone is to be understood as an arc of declination between two consecutive réseau lines on the copy of the Yerkes plate.

Table II.

(L−P).

Zone.	Approx. Distance of Centre of Zone from Centre of Group.	Number of Stars Compared.	Mean Difference of x.	Mean Difference of y.
	′ ″		″	″
1	−5 44	12	+0·44	· 0·20
2	−4 50	14	+0·57	−0·17
3	−3 57	28	+0·43	−0·22
4	−3 3	62	+0·32	−0·33
5	−2 9	86	+0·29	−0·37
6	−1 15	103	+0·32	−0·39
7	−0 22	95	+0·16	−0·52
8	+0 31	76	+0·19	−0·62
9	+1 25	37	+0·09	−0·64
10	+2 19	23	+0·14	−0·63
11	+3 13	12	+0·16	−0·34
12	+4 6	6	+0·11	−0·54
13	+4 59	4	+0·30	−0·35

Here again the mean difference is $+0''\cdot27$ and $-0''\cdot41$ in x and y respectively, practically the same as before, with some indications of regular systematic progress. But the systems by which the measures have been reduced in the two cases are essentially different; and before deciding to what extent the discrepancy in the measures is real it will be necessary to reduce the measures to some uniform plan. There are two methods which seem available: either to introduce a scale value into Dr. Scheiner's work which shall be the same as that employed in the Oxford measures, and to re-reduce the position of his normal star, or to derive the constants of the Potsdam plate *de novo*, and in the same manner and from the same stars that were used in deriving the constants of the Yerkes plate.

With regard to the first proposal it is to be remarked that Dr. Scheiner had at his command the places of seven stars out of the Lund zones, and these places, or some of them, have been used for the determination of the scale. From stars A.G.C. Lund 6829 and 6863 he has derived one value of the scale or réseau interval, and from Lund 6836 and 6868 he has derived

another; and since he has two plates taken on consecutiv evenings he obtains four results :—

	From the First Plate.	From the Second Plat
1st pair of stars	299″·87	299″·86
2nd pair of stars	299·96	299·97
Mean	299·92	299·92

This mean result looks very satisfactory; but when we intr duce the corrections (*Monthly Notices*, 1904 November, vol. lx p. 81) to the Lund stars, we get quite as accordant results thoug the means differ noticeably :—

	From the First Plate.	From the Second Plat
1st pair of stars	299″·843	299″·821
2nd pair of stars	299·868	299·888
Mean	299·855	299·855

The position of the star of reference has been derived fro A.G.C. Lund 6829 and 6868, and from A.G.C. Lund 6836 an 6857. The measured angles Δ, given on page 19, I have reduce in the ratio of 299·855 : 299·92; but I have used unchanged th angle p (the angle between the lines drawn from the star o reference to one pair of the Lund stars), and have again brough in the corrections to the places of the Lund stars given in th *Monthly Notices* already referred to. The positions of the sta of reference as given by Dr. Scheiner are

	Plate I.		Plate II.	
1st pair	$\alpha = 249^\circ\ 27'\ 39''\cdot3$	$\delta = 36^\circ\ 41'\ 5''\cdot0$	$\alpha = 249^\circ\ 27'\ 35''\cdot1$	$\delta = 36^\circ\ 4$
2nd pair	$\alpha = 249\ 27\ 39\cdot3$	$\delta = 36\ 41\ 4\cdot7$	$\alpha = 249\ 27\ 34\cdot3$	$\delta = 36\ 4$

The new values for the same star are

1st pair	$\alpha = 249^\circ\ 27'\ 39''\cdot2$[illegible]	$\delta = 36^\circ\ 41'\ 4''\cdot71$	$\alpha = 249^\circ\ 27'\ 34''\cdot99$	$\delta = 36^\circ\ 41'$
2nd pair	$\alpha = 249\ 27\ 39\cdot69$	$\delta = 36\ 41\ 4\cdot90$	$\alpha = 249\ 27\ 34\cdot75$	$\delta = 36\ 41$

The mean difference in α is $+0''\cdot27$ (or in $x+0''\cdot22$) and i $\delta-0''\cdot41$; a very close agreement with the quantity shown to b necessary to remove the constant error between the two sets o measures.

The same result is practically arrived at if the Potsda measures are compared, not directly with the Lund stars, bu with the places derived in the *Monthly Notices*. Taking th same list of stars as that previously employed, page 803, the diffe ence between Oxford and Potsdam is given by the expression

$$x_0-x_P=+0''\cdot029x_P-0''\cdot107y_P+1'\ 13''\cdot87$$
$$y_0-y_P=+0\cdot092x_P-0\cdot042y_P-\ \ 40\cdot83$$

These formulæ include the effects of (1) difference of adopte plate centres, (2) difference of central meridian, (3) difference o mean equinox, (4) changes in (a) scale value and (b) orientatio

arising from the different systems of reduction. It is unnecessary to seek in detail to what extent the total coefficients are accounted for by these sources of difference, so far as they can be separately estimated. But the coefficients $+0''\cdot029$ and $-0''\cdot042$, which represent the total difference of scale value (per minute of arc) in the direction of the two coordinates, call for remark. No geometrical reason can be suggested for the difference, and the magnitude of the discrepancy ($0''\cdot071$) is too great to be attributed with any assurance to the influence of accidental error. Hence, although the proof is by no means convincing, there is a slight suggestion that the form of the cluster as a whole is changing either by an expansion in the direction of x or a contraction in the direction of y.

Introducing these corrections into the Potsdam Catalogue, the residuals in Table II. have the following values :

Zone.	Mean Diff. of x.	Mean Diff. of y.	Zone.	Mean Diff. of x.	Mean Diff of y.
	"	"		"	"
1	−0·06	+0·02	8	−0·05	−0·14
2	−0·14	+0·07	9	−0·06	−0·07
3	−0·07	+0·04	10	+0·03	−0·06
4	+0·02	−0·11	11	0·00	+0·25
5	−0·04	+0·19	12	+0·01	+0·04
6	+0·01	−0·02	13	+0·06	+0·27
7	+0·03	+0·05	...	...	...

The smallness of the residuals shows, as was expected, that the interval of time is far too short to detect any relative motion in the stars composing the system. But the method of grouping the stars is not without its objections. It is probable that in a spherical cluster, seen projected on a plane, many of the stars apparently near each other are on opposite sides of the system and moving in opposite directions ; consequently in such cases the motions would have a tendency to counteract each other.

Magnitude.

The determination of magnitude is one of the least satisfactory parts of the inquiry. Not only is there wanting sufficient data to assist in the conversion of the measured diameters into conventional magnitudes, but the measurement of the diameters themselves is not very satisfactory. So long as the images present a well-blackened area the measurement is fairly easy, but in the faintest stars the blackening is not continuous. They consist of a certain number of darkened points which do not coalesce, and there is probably a tendency to make the measurements too large. Or if the exposure had been continued, producing still fainter stars on the plate, the images that have been measured would not have increased in diameter, but the internal parts would have become blacker. Practically, therefore, it is to

be feared that there are two scales, one
the other to the fainter stars.

Inasmuch as the total number of s
2½ times that of Scheiner's Catalogue, i
the Yerkes plate registers the position
fainter than those on the Potsdam plate
fifteenth magnitude; but it is hardly p
has been found to hold roughly among t
stars in the heavens would be maint
magnitude which have not hitherto
increase of number with decrease of
down some time, and apart from this
that the distribution of stars of variou
form. In Scheiner's catalogue the star
faintest are not those which occur m
adopted practically seven classes of ma
of those stars which it is possible to con
measures the percentages in each class

Magnitude.	Percentage.	Mag
12·4	5	1
12·5	7	1
12·7	10	1
12·8	15	

This peculiarity in the falling off in
the Yerkes plate, but another is manife
to be no explanation in the way of obse
with equal force to a want of uniform
the stars in each magnitude. Arrang
diameter in successive groups, varyi
corresponds approximately to 0″·3) we
in each group:

TABLE IV.

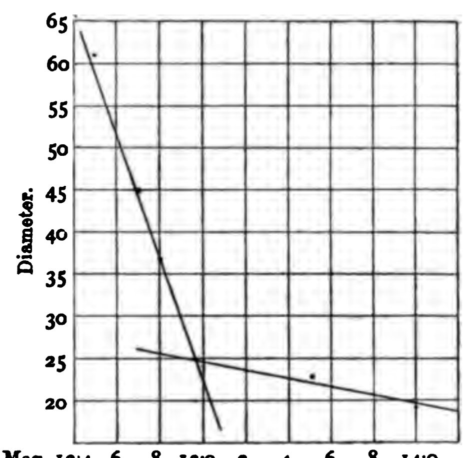
Number of Stars in each Zone, arranged

Distance from Centre.	Under 15.	15–20.	20–25.	25–30.	30–35.	35–40.	40–45.	45-
−5·44	7	5	2	1	...	...	1	..
−4·50	18	4	...	3	1	2	1	[illegible]
−3·57	12	9	3	3	3	1	1	..
−3·3	24	11	6	5	2	3	2	[illegible]
−2·9	45	32	9	4	7	7	4	
−1·15	144	64	33	10	11	13	12	[illegible]
−0·22	217	108	67	41	21	42	22	2
+0·31	214	92	45	30	10	26	13	[illegible]
+1·25	92	39	22	7	3	9	13	[illegible]
+2·19	45	15	10	3	...	4	4	
+3·13	17	19	4	1	...	3	1	..
+4 6	11	11	1	5	1	1	...	[illegible]
+4·59	10	1	...	3	1	...	...	..
+5·52	5	2	2	1	...	...	...	
Total	861	411	204	117	60	111	75	[illegible]

While the rate of increase is fairly well marked in the lower numbers there are noticeable discrepancies among the higher magnitudes, and to some extent the table demonstrates the same anomaly as that found in Scheiner's catalogue. I have attempted to determine the average diameter that corresponds to Scheiner's assigned magnitudes, as it would be obviously desirable to continue Scheiner's scale of magnitudes. The results are as follows :

Scheiner's Magnitude.	Yerkes Diameter.	No. of Stars.
12·4	65·6	28
12·5	61·4	38
12·7	44·9	56
12·8	37·1	78
13·0	24·4	139
13·5	22·9	106
14	19·1	90

Scheiner has marked two stars as of 12·2 and 11·7 magnitudes respectively ; but the diameters of these fall below the average of 12·4, and two others are described as 13·8 magnitude. These



Comparison of Measured Diameter with conventional Magnitudes.

also have been excluded from the list. If these magnitudes and diameters be plotted to scale the result points, as I have suggested, to the existence of two scales, or two distinct methods of measuring the diameter. It does not seem practical to draw a curve, even if a curve were legitimate, through the points. The diameters of the brighter stars lie on one straight line, and the diameters of the fainter on another. This is shown on the accompanying diagram where a linear relation apparently exists between both the brighter and the fainter stars. Four hours'

exposure with the Yerkes telescope would undoubtedly impr the images of fainter stars than those of the fourteenth mag tude, but the effect of the yellow screen is not known. B considering that Scheiner must have included some stars bel the fourteenth magnitude in his faintest group, and after allo ing for the over-estimation of the diameters of the faintest st on the Yerkes plate, it seems not improbable that the number stars brighter than the fifteenth magnitude does not great exceed 2,000.

The Distribution of Stars in the Cluster.

A question of greater interest seems to be to attempt determine the law of density in the cluster itself, and t larger number of stars with which we have to deal than were the command of Professor Scheiner makes the attempt a litt more promising. There is, of course, some difficulty in derivi the number of stars in a definite area of various distances fro the centre, but a tolerable approximation has been effected b dividing each square of the réseau (53″ of side) into four equ portions, and counting the number of stars in each quarte These numbers were plotted in a diagram from which could b obtained the average number in a small square at uniform distanc from the centre. At the centre of the cluster the number of sta in a square whose side was approximately twenty-seven secon was sixty-five, and the cluster has been assumed to extend the directions x and y to six minutes from the centre. At th distance about one star was found in each réseau square, a therefore the influence of the cluster may be supposed to ha disappeared. In this way we have the apparent distribution the stars when projected on a plane at right angles to the line sight.

On the assumption of general radial symmetry let $f(r)dv$ the number of stars in a small volume dv situated at a distan r from the centre of the cluster. Let x be the projection of r the plane at right angles to the line of sight, and θ the ang between r and x. Then if a cylinder of small section da taken through the cluster with its axis parallel to the line sight and at a distance x from the centre of the cluster, th number of stars to be seen within it is

$$\int f(r)da\,d(x\tan\theta)$$

where $x = r\cos\theta$ and the limits of the integral correspond to th boundary of the cluster. Eliminating θ and equating to $\phi(x)d$ the number of stars within the area da in the apparent distrib tion, we get

$$\phi(x) = 2\int_x^1 rf(r)\frac{dr}{\sqrt{r^2-x^2}}$$

the radius of the cluster being taken to be unity. If r be eliminated instead of θ, we get

$$\phi(x) = 2x\int_0^{\theta'} \sec^2\theta f(x\sec\theta)d\theta$$

Here the upper limit θ' corresponds to the boundary and is a function of x when the radius of the cluster is finite. If the radius can be considered infinite the upper limit becomes $\frac{1}{2}\pi$. Hence if $f(r)$ can be expressed in the form $\Sigma a_n r^{-n}$, $\phi(x)$ has the corresponding form $\Sigma A_n x^{-n+1}$, where

$$A_n = 2a_n\int_0^{\frac{\pi}{2}} \cos^{n-2}\theta d\theta$$

When the law of density is expressed by one term only, this can easily be found; for in this case

$$\log\phi(x) = \log A_n - (n-1)\log x$$

which gives a straight line when plotted with $\log x$ and $\log\phi(x)$ as coordinates. In the present case the graph shows distinct curvature, indicating that the law of density cannot be well represented by this simple form. The effect of a finite boundary to the cluster was next considered, but without an entirely satisfactory result. It seems probable that if the law of density is of this type, it requires more than one term for its expression.

When the radius of the cluster is supposed to be finite, a simple type of the law of density is represented by some positive power of the distance from the boundary. The radius being taken as unity, this law is expressed by $f(r) = (1-r)^n$.

In this case

$$\phi(x) = 2\int_x^1 r(1-r)^n \frac{dr}{\sqrt{r^2-x^2}}$$

$$= 2\left[(1-r)^n\sqrt{r^2-x^2}\right]_x^1 + 2\int_x^1 n(1-r)^{n-1}\sqrt{r^2-x^2}dr$$

where the first term on the right vanishes at both limits. Let

$$Z_n = \int_n^1 (1-r)^n \frac{dr}{\sqrt{r^2-x^2}}$$

The equality of the above integrals shows that

$$Z_n - Z_{n+1} = n[Z_{n+1} - 2Z_n + (1-x^2)Z_{n-1}]$$

or

$$(n+1)Z_{n+1} - (2n+1)Z_n + n(1-x^2)Z_{n-1} = 0$$

Let

$$Y_n = Z_n - Z_{n+1}$$

so that

$$-(n+1)Y_n + nY_{n-1} - nx^2Z_{n-1} = 0$$

$$-nY_{n-1} + (n-1)Y_{n-2} - (n-1)x^2Z_{n-2} = 0$$

Then the result of eliminating the Z functions becomes

$$(n^2-1)Y_n - n(2n-1)Y_{n-1} + n(n-1)(1-x^2)Y_{n-2} = 0$$

Now $\phi(x) = 2Y_n$ and

$$Y_1 = \tfrac{1}{2}a - \tfrac{1}{2}b,\ Y_2 = \tfrac{1}{3}(2x^2+1)a - b$$

where

$$a = (1-x^2)^{\frac{1}{2}},\quad b = \tfrac{1}{2}x^2 \log_e (1+a)/(1-a)$$

When $x = 0$, $Y_1 = \frac{1}{2}$ and $Y_2 = \frac{1}{3}$, which shows t
$Y_n = \dfrac{1}{n+1}$, for the solution of the difference equation in t
case is clearly

$$Y_n = A/(n+1) + Bn$$

Hence if we put $\phi_n(x) = (n+1)Y_n$ we make the central dens
in the apparent distribution unity. The difference equati
becomes

$$(n-1)\phi_n - (2n-1)\phi_{n-1} + n(1-x^2)\phi_{n-2} = 0$$

with the initial values

$$\phi_0 = a,\ \phi_1 = a-b,\ \phi_2 = (2x^2+1)a - 3b$$

These can be calculated numerically for convenient intervals
x, and the values of $\phi_3, \phi_4 \ldots$ can be easily deduced in successi
by means of the difference equation. When the process has
be carried to considerable values of n, it is of course necessary
begin with a greater number of decimal places than are ul
mately required on account of the accumulation of numeri
error. In this way the following table has been calculated :

n/x.	0·0.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.	1
0	1·000	0·995	·980	·954	·917	·866	·800	·714	·600	·436	[illegible]
1	1·000	·965	·888	·785	·666	·537	·405	·275	·156	·057	[illegible]
2	1·000	·925	·783	·620	·458	·311	·190	·097	·037	·007	[illegible]
3	1·000	·880	·679	·477	·305	·174	·085	·033	·008	·001	[illegible]
4	1·000	·831	·582	·362	·200	·095	·038	·011	·002		
5	1·000	·782	·494	·271	·129	·051	·016	·003			
6	1·000	·733	·417	·202	·083	·027	·007				
7	1·000	·684	·350	·149	·052	·014	·003				
8	1·000	·637	·292	·109	·033	·007	·001				
9	1·000	·592	·243	·080	·021	·002	·001				
10	1·000	·549	·202	·058	·013						
11	1·000	·509	·167	·042	·007						
12	1·000	·470	·137	·030	·004						·0

When these values are plotted they give curves which represent the general character of the observed distribution of density. For a good agreement a large value of n seems necessary. As n increases the curves tend to similarity, and the uncertainty in the radius of the cluster makes it impossible to attach any great weight to the determination of n. With the diameter already mentioned a fair representation is obtained by assuming $n = 11$. Unfortunately it is not easy to show the comparison graphically except on a very large scale, as the variation from straight line is small in the greater part of the curve, and the various curves have a tendency to coalesce. But assuming a central density of sixty-five stars in a unit of space, the number of stars read from the curves can be compared numerically with the values computed from the above table.

Distance from Centre.	No. of Stars Observed.	No. of Stars $n=8$.	No. of Stars $n=9$.	No. of Stars $n=10$.	No. of Stars $n=11$.
0″	65·0	65·0	65·0	65·0	65·0
45	33·4	41·4	38·5	35·7	33·1
93	12·7	19·0	15·8	13·1	10·9
136	5·0	7·1	5·2	3·8	2·7
188	2·3	2·2	1·4	0·8	0·5
258	1·1	0·5	0·1		

The agreement is not very satisfactory in any case, but it seems safe to say that while n may be as high as 11, it is not less than 8. Professor Geo. E. Hale has offered me a plate on which the number of images recorded is much larger than on the plate here discussed, and I hope to return to this question again.

The discussion as far as it goes affords an example of the spirit of devolution of which we have heard something of late, and I acknowledge my indebtedness to the Directors of the Yerkes and Oxford Observatories, and to others, who have enabled me to carry out this investigation.

1905 *June* 5.

The Solar Rotation Period from Greenwich Sun-spot Measures, 1879–1901. By E. Walter Maunder and A. S. D. Maunder.

1. *Material Employed.*

The material employed in the following paper is much more ample than has been used in any previous discussion of the solar rotation. It is drawn from the Photoheliographic Results published in the annual volumes of the *Greenwich Observations*, and especially from the ledgers of sun-spots. From the 4700 spot-groups catalogued in these results for the twenty-three years (1879–1901) we have taken every group which persisted

for six or more days—1872 in number. A very few group this duration were excluded, because the record was in s way defective. For the sake of symmetry the last groups of cycle, which expired in 1879, and the first groups of the cy which began in 1901, have been left out of the discussion, wh is thus limited to the two complete cycles. These two cy will be referred to hereafter as cycle 1 and cycle 2—cycl attaining its maximum in 1883, and cycle 2 in 1893. It may noted here that when sun-spots are treated, as in this discussi in narrow zones of latitude, there is (broadly speaking) not slightest possibility of ambiguity as to which of the two cycle given group belongs. The break between the two cycles in particular latitude generally lasts for something like three f years during which no spots whatsoever, not even the m minute, appear in that particular zone. The time when t break takes place differs for different zones; but for a particular zone this entire cessation of activity is one of t most unmistakable characteristics of solar variation.

The material has been used in two ways. First, each appa tion of a spot-group has been used independently of any oth apparition of the same. Second, the spot-groups have been ca fully examined for cases of return, and where it appeared cle that the same group has returned a second time or more fr quently, without any temporary disappearance or subsiden such a long-continued group has been treated as an enti throughout. But in both methods the entire spot group h been taken as a whole on each day of observation, the centre gravity of the entire group being taken as the position of t group on that particular day. There has been no selection spots because they seemed to be steady in motion or regular shape, no rejection because of unsteadiness or irregularity. T only criterion for the inclusion of a group in the discussion h been that it lasted for six consecutive days; subject to t caution that when a group on a certain day was close to t limb, and there was reason to fear from a marked and sudd change of area or position that the entire group was not view, that day was not used. If on the first or last day observation the group was within 70° of the central meridia then the group was retained, no matter whether the measur appeared accordant or not. If the distance from the centr meridian was much greater than 70° on any day, then that day measures were only retained if there was clear indication th the whole of the group was still within the visible hemisphere.

The method of reduction employed was very simple, b seemed sufficiently effective for the purpose in view. The me of the positions of the group on the first three days was taken the first position of the group; the mean of the positions on t last three days as the second position; the difference betwe the two longitudes thus given divided by the number of day and parts of a day gave the mean daily drift, eastward or wes

rd according to its sign. Thus a group observed on six con-utive days would have its mean position determined for the ond and fifth days, giving an interval of three days. The gest period during which a group can be observed during a gle apparition is fourteen days, and it was of course extremely e under these circumstances that both the first and the last ervations could be regarded as complete. A fourteen-day up, where all the fourteen days could be used, would thus give interval of eleven days.

In the case of the long-continued spots, that is to say, of ts that have been seen during more than one apparition, the an of the first five days of the first apparition has been npared with the mean of the last five days of the last appari-n, wherever this was possible. As in the former case, days observation when the group was imperfectly seen at either limb re not been included.

The term "solar rotation period" is not used in this paper in rigid sense. Strictly speaking, the Sun can have but one ation period, but an inquiry like the present, confined entirely the apparent movements of spot-groups, necessarily deals with resultant effect of such solar rotation period and of the tions of the groups, whether such motions are systematic, or egular, or both. To speak, for example, of the solar rotation iod as derived from a single group, possibly short-lived, and ving at an unusual speed, would be quite inexcusable if it re not clearly pointed out that the expression was used partly brevity and convenience, and partly because the solar rota-n period is, after all, much the most considerable factor, as well the most permanent in the apparent movements of the spots on the solar disc.

2. *Each Apparition treated separately.*

In the reduction of the measures of the solar photographs at eenwich Carrington's value for the mean sidereal rotation iod of the Sun has been adopted throughout. This period is 38 days, corresponding to a daily sidereal angular motion of 1'·06. The first operation in the discussion of the observations s to ascertain for each group the amount of its apparent daily ft in longitude as computed with this constant. The "drifts" is obtained have been combined in various ways, the first empt being to find an expression for the variation of the ation rate in different solar latitudes. Table I. exhibits the ult of treating the spots in zones of latitude each $5°$ wide. e centres of these zones have been taken $2\frac{1}{2}°$ apart, starting m the equator and proceeding in either direction. Thus ry group has been used twice, except the groups in the two erior half-zones. This is the only smoothing that has been d. The weighting has been strictly in proportion to the nber of days' interval given by each group; that is to say, a

Table II. exhibits the distribution of the spot-groups i table of double entry, the horizontal lines showing the numb of groups yielding different synodic rotation periods, the verti columns, the numbers of groups in each zone of latitude 5° wi

This table brings out a most important point which l hitherto been practically entirely neglected, namely, the way which the apparent spot movements in any particular zone latitude differ among themselves. It will be seen that t differences of rotation period of the various groups in a particular zone of latitude are much greater than the differen of mean rotation between the different zones. The extre differences shown in Table I. lie between 26·3 days and 2(days (synodic rotation periods); that is to say, within extreme range of 2·7 days. The groups with periods betw these limits have been printed in heavier type in Table II. we turn to this latter table we see that in one particular zone latitude, +10° to +15°, the extreme range is from 24·4 days 31·2 days. In other words, if these spots persisted for ni consecutive rotations and travelled continuously at the san rate, the most quickly moving spot would make ten rotatio and the most slowly moving only eight rotations, whilst the spo with mean period would be completing nine. The bearing of th fact upon the inquiry into the connexion between sun-spots an magnetic disturbances is obvious. It is not in the least nece sary to presume that a disturbance indicating a long rotatio period is due to a spot in high latitude. It is perfectly tru that when we are dealing with the *mean* motions in any zone w find that the rotation period generally lengthens with th distance from the equator; but, as Table II. also shows, th individual spot-groups giving the longest periods are by n means situated in the highest latitudes.

A more detailed examination of the table shows that abov 25° latitude, north or south, there is scarcely any tendency i the spot groups to concentrate upon one particular period. Th higher the latitude the more evenly are the groups scattere amongst the different rotation periods; a fact which has a important bearing upon the law of the variation of rotation rat with latitude. Carrington's expression for the rotation perio involves the term $\sin^{\frac{7}{4}}\lambda$, and Spoerer's the term $\sin(41° 13'+\lambda)$ The fractional exponent in the one case and the auxiliary angl in the other are refinements which have no warrant in th observations. It is perfectly clear that beyond 25° from th equator we can attach no great precision to the rotation perio derived from spot-groups, since groups in higher latitudes ar not only few in number, but appear almost accidental in th rotation periods which they yield; so that there is no justi fication for departing from a simple expression of the forn $a-b\sin^2\lambda$. The formula $875'{\cdot}7 \mp 164'\sin^2\lambda$ satisfies the obser vation sufficiently well for all but the extreme latitudes, as wil be seen by the eighth and ninth columns of Table I., which give

respectively the values of the daily angular movement as computed by this formula, and the differences of the observations from them.

The important discovery of Carrington of what has been described as "the systematic variation of rotation rate from equator to poles" has generally obscured this striking and remarkable variety in the motions of spots in any given latitude. It has been forgotten that, whatever the cause which produces this variation of rotation rate with latitude, the causes producing difference of rate within any given latitude are more effective still.

The question has been raised as to whether the mean rotation period of the Sun as derived from the spots varies from cycle to cycle, or in different parts of the progress of any one cycle. Table III. exhibits the daily sidereal movement for the different zones of latitude for the two cycles treated separately; it thus corresponds to Table I.; but to save space the two columns of mean synodic and mean sidereal rotation periods have been omitted. The comparison of the table emphasises the remark just made that there is no sufficient warrant for seeking a more complicated expression than one of the form $a-b\sin^2\lambda$, the differences between the results given by the two cycles being often so considerable.

TABLE III.

Comparison of the Two Cycles.

Latitude.	Cycle I. No. of Groups.	Cycle I. Weight.	Cycle I. Daily Sidereal Motion.	Cycle II. No. of Groups.	Cycle II. Weight.	Cycle II. Daily Sidereal Motion.	I.–II.
+35°	1	4	789′·3	1	8	812′·8	−23′·5
32½	0	0	...	3	21	827·5	...
30	2	9	818·2	9	62	834·4	−16·2
27½	13	78	821·9	23	134	849·6	−27·7
25	24	147	822·8	42	253	848·3	−25·5
22½	50	295	844·3	65	408	854·3	−10·0
20	61	358	853·1	106	660	861·7	− 8·6
17½	58	335	864·0	130	839	864·9	− 0·9
15	101	634	861·7	140	953	867·9	− 6·2
12½	124	796	865·1	167	1138	868·1	− 3·0
10	93	580	871·5	153	1012	870·5	+ 1·0
7½	58	360	874·6	96	627	873·8	+ 0·8
5	36	228	880·1	63	401	875·3	+ 4·8
+ 2½	21	136	880·6	42	256	878·4	+ 2·2
0	19	113	868·9	22	143	880·5	−11·6
2½	35	224	874·1	35	229	874·7	− 0·6
5	65	413	870·1	83	544	872·9	− 2·8

Latitude.	Cycle I. No. of Groups.	Cycle I. Weight.	Cycle I. Daily Sidereal Motion.	Cycle II. No. of Groups.	Cycle II. Weight.	Cycle II. Daily Sidereal Motion.	L-I
°			′				′
– 7½	110	708	867·8	130	862	870·7	– 2
10	126	804	867·9	163	1070	868·9	– 1
12½	110	671	868·2	184	1196	866·1	+ 2
15	114	713	865·5	163	1027	862·7	+ 2
17½	104	662	862·0	148	911	860·2	+ 1
20	66	424	854·0	122	771	857·8	– 3
22½	38	239	854·0	72	457	851·8	+ 2
25	21	117	849·6	48	305	844·0	+ 5
27½	12	71	832·5	32	202	847·1	–14
30	7	46	829·9	17	104	843·4	–13
32½	2	11	844·2	7	39	818·6	+25
–35	1	6	843·4	2	6	791·8	+51

One most remarkable peculiarity is common to both cycles and since it was brought out by Carrington's inquiry two cycl earlier than the first of these it is probable that it expresses real peculiarity of the solar rotation. In spite of the gre irregularity in the rotation periods given by the spots in an particular zone, there does appear to be a distinct tendency fo the shortest mean period to be given, not at the equator, bu slightly to the north of it. The curve given by the differen rotation periods is not precisely symmetrical with respect to th equator, and, *on the whole*, there appears to be a tendency for th periods in the northern latitudes to lengthen more rapidly wit distance from the equator than with those of the southern. Th question as to any variation in the rotation period during th progress of a cycle is a particularly difficult one to answe satisfactorily, since there is a well-defined tendency for the spo to seek special latitudes at different parts of the cycle; an consequently, as at the beginning of a cycle most of the spots a in high latitudes, and at the end in low, the mean rotatio periods tend to shorten as the cycle progresses, and it is difficu to ascertain whether this effect is wholly a function of Spoerer "Law of Zones," or whether some further cause is also at worl

In Table IV. the two cycles under discussion have bee divided into three portions; three years in each cycle have bee considered as years of maximum, viz. 1882–4 in the first cycl 1892–4 in the second cycle, and have been taken as the cent periods. The years preceding these are the years of increasin those succeeding them of decreasing activity. The examinatio has been confined to the zone 10° to 22½° in each hemisphe since the latitudes higher than this belt are scarcely represent at all during decrease, and the latitudes lower than it are i like manner scarcely represented during increase. The co

зon shows that there is no clear evidence of anything like a
эmatic change in the rotation period during the progress of
particular cycle, and very little evidence, if any, of a change
ı one cycle to another.

TABLE IV.

mparison of the Rotation Periods given by Different Cycles and Different Parts of a Cycle.

.	Cycle.	Phase of Cycle.	No. of Groups.	Apparent Mean Daily Drift.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Mean Sidereal Rotation Period.
				′	d	′	d
h	I.	Increase	73	+ 4·4	27·12	855·4	25·25
		Maximum	112	+ 13·7	26·81	864·8	24·97
		Decrease	34	+ 12·8	26·84	863·8	25·00
		Entire cycle	219	+ 10·6	26·92	861·7	25·07
	II.	Increase	51	+ 17·0	26·70	868·1	24·88
		Maximum	187	+ 15·2	26·76	866·2	24·93
		Decrease	98	+ 14·3	26·79	865·3	24·96
		Entire cycle	336	+ 15·2	26·76	866·2	24·93
h	I.	Increase	36	+ 13·1	26·83	864·1	24·99
		Maximum	126	+ 11·9	26·87	863·0	25·03
		Decrease	76	+ 10·2	26·93	861·3	25·08
		Entire cycle	238	+ 11·5	26·88	862·6	25·04
	II.	Increase	23	+ 11·5	26·89	862·5	25·04
		Maximum	204	+ 9·5	26·95	860·5	25·10
		Decrease	149	+ 14·7	26·78	865·8	24·95
		Entire cycle	376	+ 11·6	26·88	862·7	25·04
pots	I.	Increase	109	+ 7·2	27·03	858·3	25·17
		Maximum	238	+ 12·8	26·84	863·8	25·00
		Decrease	110	+ 11·0	26·90	862·0	25·05
		Entire cycle	457	+ 11·0	26·90	862·0	25·05
	II.	Increase	74	+ 15·2	26·76	866·3	24· 3
		Maximum	391	+ 12·2	26·86	863·3	25·02
		Decrease	247	+ 14·5	26·78	865·5	24·95
		Entire cycle	712	+ 13·3	26·82	864·4	24·98
pots	Both cycles	Increase	183	+ 10·6	26·92	861·7	25·07
		Maximum	629	+ 12·4	26·85	863·5	25·01
		Decrease	357	+ 13·4	26·82	864·5	24·98
		Entire cycle	1169	+ 12·5	26·85	863·6	25·01

The very slight diminution of the period with the progres the cycle shown by the last section of Table IV. may be loo upon as purely accidental, for it will be observed that the nortl spots in the second cycle and the southern spots in the first c showed quite as distinct a progression in the other direct We may conclude, therefore, that there is no evidence of a cha in the rotation period during the progress of the cycle other t that which results from the change in the distribution of the sp in latitude.

But if we compare together spots of different durations th does seem some distinct evidence of a systematic differe Table V. brings this out. The spots are divided into three class those observed on six or seven days are regarded as short-li spots; those on eight, nine, or ten, as spots of medium durati and those of eleven, twelve, thirteen, and fourteen days, as lo lived. In order to complete the comparison we have added recurring spots, and it will be noted that there is on the wh a distinct tendency for the short-lived spots to give a shor rotation period than those of longer duration.

Table V.

Comparison of the Rotation Periods given by Spots of Different Duration

Hemi-sphere.	Cycle.	Duration of Group.	No. of Groups.	Weight.	Apparent Mean Daily Drift.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Me Sider Rotat Peri
					′	d	′	d
North	I.	Short	79	275	+ 9·5	26·95	860·5	25·
		Medium	141	853	+ 15·4	26·75	866·5	24·
		Long	105	876	+ 9·2	26·96	860·3	25·
		Recurrent	99	3449	+ 7·8	27·01	858·8	25·
	II.	Short	127	445	+ 23·0	26·50	874·0	24·
		Medium	175	1061	+ 19·8	26·61	870·9	24·
		Long	224	1917	+ 11·3	26·89	862·3	25·
		Recurrent	133	4980	+ 5·8	27·07	856·9	25·
South	I.	Short	107	376	+ 17·9	26·67	868·9	24·
		Medium	156	944	+ 20·2	26·60	871·3	24·
		Long	149	1272	+ 5·6	27·08	856·6	25·
		Recurrent	125	8572	+ 6·6	27·05	875·7	25·
	II.	Short	157	545	+ 21·5	26·55	872·6	24·
		Medium	209	1260	+ 15·7	26·74	866·8	24·
		Long	242	2091	+ 7·3	27·03	858·3	25·
		Recurrent	167	11150	+ 5·1	27·10	856·1	25·
Both	Both	Short	470	1641	+ 19·0	26·63	870·1	24·
		Medium	681	4118	+ 17·8	26·67	868·8	24·
		Long	720	6156	+ 8·5	26·98	859·5	25·
		Recurrent	524	19722	+ 6·1	27·07	857·2	25·

3. *Recurring Sun-spots.*

Table VI. presents for the recurring spot-groups the same statistics as were given in Table I. for the several groups considered independently at each apparition. It has not been thought worth while to give a table for these long-lived groups similar to Table II., but Table VII., corresponding to Table III., gives a comparison of the two cycles for these recurring groups. There is no doubt that these groups are much more free from the effect of accidental motions than the groups when considered separately in each apparition. The mean sidereal period given by them is exactly

$$25{\cdot}2 \text{ days}$$

and the formula which satisfies the variation of rotation period with latitude, and has been adopted in Table VI., is

$$866'{\cdot}6 \mp 128' \sin^2 \lambda$$

TABLE VI.

Rotation Periods from Recurrent Spots for Different Zones of Latitude.

Latitude.	No. of Groups.	Weight.	Apparent Mean Daily Drift.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Mean Sidereal Rotation Period.	Daily Sidereal Motion computed.	O−C.
°			′	d	′	d	′	′
+30	3	92	−23·9	28·12	827·1	26·12	834·6	−7·5
27½	10	364	−12·8	27·72	838·2	25·69	839·3	−1·1
25	19	704	− 6·8	27·51	844·2	25·59	843·7	+0·5
22½	38	1401	− 1·8	27·34	849·3	25·42	847·9	+1·4
20	54	1909	+ 3·3	27·16	854·4	25·28	851·6	+2·8
17½	57	1985	+ 7·0	27·04	858·0	25·18	855·0	+3·0
15	62	2143	+ 8·4	26·99	859·5	25·13	858·0	+1·5
12½	76	2904	+10·0	26·94	861·0	25·09	860·4	+0·6
10	65	2552	+11·0	26·90	862·1	25·06	862·9	−0·8
7½	32	1203	+14·8	26·78	865·8	24·95	864·4	+1·4
5	25	870	+18·2	26·66	869·2	24·86	865·6	+3·6
+ 2½	19	572	+17·0	26·70	868·1	24·88	866·4	+1·7
0	11	398	+15·1	26·76	866·2	24·94	866·6	−0·4
− 2½	21	693	+16·5	26·72	867·6	24·90	866·4	+1·2
5	38	1356	+13·1	26·83	864·2	24·99	865·6	−1·4
7½	65	2742	+10·7	26·91	861·7	25·06	864·4	−2·7
10	75	3249	+ 9·7	26·94	860·8	25·10	862·9	−2·1
12½	80	3198	+ 9·5	26·95	860·6	25·11	860·4	+0·2
15	79	3021	+ 8·5	26·98	859·6	25·13	858·0	+1·6
17½	68	2395	+ 4·5	27·12	855·6	25·24	855·0	+0·6

All spots ...
Carrington

Co

Latitude.	Cycle I.
°	′
+ 30	823·9
27½	828·5
25	838·3
22½	845·0
20	850·0
17½	857·9
15	860·2
12½	864·7
10	865·2
7½	865·3
5	871·4
+ 2½	869·6
0	864·7
− 2½	867·8
5	864·3

The Greenwicl
1879–1901 give u
(1) Carringt

the latter—the recurrent spots—give a somewhat longer period in the mean, and are more accordant *inter se* than are the groups treated separately.

(4) The curve given by the different rotation periods is not precisely symmetrical with respect to the equator, the zone of shortest rotation being north of the equator.

(5) The rotation periods given by different spots in the same zone of latitude differ more widely than do the mean rotation periods for different zones of latitude.

(6) Spots of short duration tend to give a shorter rotation period than spots of long.

(7) There is no evidence of a progressive change in the mean rotation period during the progress of a sun-spot cycle other than that which follows from the gradual shift of sun-spot activity from higher to lower latitudes.

(8) A comparison of the rotation periods from the separate groups for the two cycles shows an apparent slight shortening of the period for the northern hemisphere whilst the southern is absolutely unchanged. It cannot be presumed that this apparent change in the northern hemisphere is anything but accidental.

(9) For when the recurrent spots are taken there is a slight retardation of the rotation period from the first cycle to the second, shown by both northern and southern hemispheres.

86 Tyrwhitt Road, St. John's, S.E.:
1905 *June* 9.

Observations of Mars, 1903. By Major P. B. Molesworth, R.E.

The apparition of 1902–3 was rather an unfavourable one, as the diameter of the planet at opposition was only $14''\cdot57$. The great tilt, however, of the axis presented the northern regions in most favourable position for observation, and the small diameter of the polar cap permitted the details to be followed up nearly to the pole. The southern regions of course were greatly foreshortened.

Vernal equinox, N. hemisphere	1902 August 12
Aphelion of *Mars*	1903 January 13
Summer solstice, N. hemisphere	February 27
Mars in opposition	March 29
Autumnal equinox, N. hemisphere	August 28

The north latitude of the centre of the disc decreased from $+22^{\circ}\cdot6$ on January 17, when the observations began, to $+21^{\circ}\cdot09$ on February 2, increasing again to $+25^{\circ}\cdot9$ on June 2, after

month.

Month. 1903.		Total Nights.	Numbe[r] of Night[s] Avail-able.
Jan.	... ...	14	...
Feb.	... ...	12	...
		16	16
Mar.	... ...	31	15
Apr.	... ...	30	24
May	... ...	31	29
June	... ...	7	7
		23	...
July	... ...	31	...
Aug.	... ...	31	...
Sept.	... ...	21	...
Total for period of regular observations		115	91
Grand total	...	247	...

During the peri
the weather was, a
conditions were v
being perfectly tra
observation, and
perfect steadi...

ꞔer, R.E., and two rough sketches by my brother, Mr. T. L. Molesworth. Of these drawings I forward copies of ɔf the most characteristic, which may be regarded as showing typical appearance of the various aspects of *Mars* in 1903.
[carefully measured the mean coordinates of a number of the t prominent markings upon a large number of the sketches. ːffect this a large disc of *Mars* was drawn and the lines of ıude and longitude inserted with the proper tilt of the axis. ; diagram was then reduced by photography to the exact size he disc blanks used for the drawings. Transparencies were ı made by contact on lantern plates, and purposely very tly developed, so as to leave the white absolutely clear glass. glass positive was placed over each drawing and correctly ɔted as far as possible. The coordinates of the required kings within 30° of longitude of the central meridian were ı read off and corrected for the longitude and latitude of the re of the disc at the time of the drawing. In addition to above, central meridian transits of various points were taken eye near the opposition. The values obtained by both ɔods and the resultant coordinates adopted are given in le II. (Table V. in the manuscript).

Table II.

Coordinates of Points.

Point.	Longitude. Measured from Drawings.	No.	From C.M. Transits.	No.	Adopted Value.	Latitude measured from Drawings.	Remarks.
	°		°		°	°	
ı estuary ...	5·4	9	6·1	3	5·5	− 5·5	
Fons	5·9	7	9·1	1	6·5	+ 30·3	
ıiamata (centre)	...	...	10·8	1	...	...	
Palus	16·0	9	22·9	1	18·0	+ 13·0	
Acidalium (lake)	18·5	17	18·4	2	18·5	+ 47·0	
„ „	24·2	16	...	...	24·2	+ 35·0	
ıritifer Sinus ...	22·3	13	33·0	2	26·0	− 5·0	
꞉us L. (E. end)...	28·5	11	...	...	28·5	+ 27·5	
Acidalium (lake)	28·9	12	33·3	1	29·5	+ 56·2	
. Aromatum ...	...	...	40·7	2	...	...	
Acidalium (lake)	41·5	11	...	...	41·5	+ 31·7	
꞉us L. (W. end) .	46·5	12	...	...	46·5	+ 24·0	
Acidalium (lake f.)	52·8	14	...	...	52·8	+ 30·1	
æ Sinus ...	54·8	11	59·7	1	55·5	− 10·3	
ɜis Lacus" ...	63·0	14	...	...	63·0	+ 52·2	
r estuary ..	62·4	7	64·6	1	63·0	− 28·7	
L. (centre) ...	65·7	11	...	...	65·7	+ 17·5	
perboreus (centre)	68·2	9	...	...	68·2	+ 77·4	

Point.	Longitude. Measured from Drawings.	No.	From C.M. Transits.	No.	Adopted Value.	Latitude measured from Drawings.	Remark[s]
	°		°		°	°	
Tithonius L.... ...	82·0	9	81·7	4	81·8	−14·3	
Lacus Solis (centre) .	87·2	7	84·9	5	86·0	−31·1	
Mareotis L. (E. end) .	95·0	10	...	...	95·0	+31·9	
Lacus Phœnicis ...	97·1	8	...	...	97·1	−18·8	
Junction of Tanaïs and Ceraunius W. ...	...	...	99·2	1	...	...	
Ascræus L.	104·8	6	...	...	104·8	+ 8·3	
Centre white spot (Arcadia)	...	...	112·5	2	112·5	...	
Arsia Sylva	120·0	2	114·0	2	114·0	− 5·0	
Mareotis L. (W. end)	118·3	12	121·0	2	119·0	+24·0	
Bocca Sirenum ...	121·7	7	130·6	2	125·0	−20·0	
Mœotis Palus ...	128·8	10	123·0	2	127·0	+52·9	
Nodus Gordii ...	135·5	3	136·4	1	133·0	+ 6·2	Ad. lat. +
Phrygius Lacus ...	147·0	11	...	...	149·0	+ 7·0	„ +1
Castorius L. (E. end)	152·0	4	...	...	152·0	+45·7	
Euxinus L.	158·1	12	159·3	4	158·5	+38·7	
Arsenius L.	162·0	2	...	...	...	+60·0	
White polar spot F. (E. end)	162·8	5	...	...	162·8	+77·0	
Titanum Sinus ...	166·0	9	166·2	1	166·0	−19·2	
Ammonium	167·0	7	...	...	167·0	+14·7	
Erebi Fons	169·6	5	...	...	169·6	+26·6	
Propontis	176·4	9	185·1	1	176·5	+39·1	
Trivium Charontis ...	200·0	6	205·4	3	201·0	+15·1	
Stygia Palus... ...	203·6	4	...	...	203·6	+26·0	
Laestrygonum Sinus .	203·7	4	...	...	203·7	−15·4	
Pambotis L.	221·1	7	225·7	2	222·0	+ 6·6	
Morpheos L.... ...	222·4	5	...	...	222·4	+31·6	
Cyclopum Sinus ...	225·0	6	...	...	225·0	−13·3	
White polar spot F. (W. end)	241·8	3	...	...	241·8	+76·8	
M. Cimmerium (W. end)	253·5	6	248·5	(2)	251·5	+ 4·8	
Nubis L. (centre) ...	254·0	10	251·8	(2)	253·0	+27·1	
Oniri Palus	260·1	7	...	...	260·0	+39·1	
Syrtis Minor... ...	267·3	6	...	...	267·3	− 0·8	
"Casius L"	268·6	7	...	...	268·6	+46·5	
Mœris L.	281·3	9	...	...	281·3	+12·2	

Point.	Longitude. Measured from Drawings.	No.	From O.M. Transits.	No.	Adopted Value.	Latitude measured from Drawings.	Remarks.
L.	283°·8	5	° ...	...	283°·8	+35°·4	
; L.	285·0	9	278·9	1	284·0	+56·1	
l Syrtis Major .	286·1	10	288·4	1	286·5	+27·6	
circular spot ...	287·6	5	...	...	287·6	+ 7·8	
Lacus... ...	293·9	6	...	...	293·9	+ 9·3	
boras L." ...	295·7	12	...	...	295·7	+20·3	
; (centre) ...	296·0	2	...	...	296·0	−37·0	
Palus	296·1	11	...	...	296·1	+42·2	
; (N. end) ...	297·0	3	...	...	297·0	−24·3	
pus L."... ...	297·8	6	...	...	297·8	− 9·0	
nis L.	308·4	10	...	...	308·4	+ 3·7	
aonis Cornu ...	313·7	11	...	...	313·7	−10·6	
bis L."... ...	320·5	1	...	...	...	+21·0	
usa L.	328·1	11	...	...	328·1	+56·2	
ius L.	329·9	13	337·0	2	332·0	+37·8	
Portus ...	337·2	10	337·6	3	337·3	− 8·3	
(centre) ...	...	...	348·4	1	...	...	
ygia Fons" ...	351·5	2	...	...	348·0	+54·0	
;kel estuary ...	355·5	12	0·2	1	356·0	− 6·0	
gium Aryn ...	358·5	2	...	...	358·5	− 6·0	

Part II. follows here in the manuscript, and gives a detailed ·iption of the various markings on the planet in order, the et being divided for the purpose into eight regions; the belt 7 within 60° of the equator on either side being divided into egions, each about 60° of longitude in breadth, whilst the areas in 30° of the South Pole and of the North Pole form the uth and eighth regions respectively. Table III., given below le VI. in the manuscript], shows the number of drawings lable for the study of each region. The six drawings selected ·eproduction represent the chief features of the six divisions e equatorial belt, together with the north polar region. The h polar region was practically invisible during the whole of ipparition. Key maps are also added, in which Schiaparelli's enclature, with the amendments of the latest Mars Report of British Astronomical Association, has been followed through-except in part of the Syrtis Major, where Lowell's nomen-ure appeared more suited to the configurations of the year er discussion. Here and there Major Molesworth has given a isional name of his own to features which appear to be new or erto unnamed.—The Secretaries.)

TABLE III.

Sect.	Limits of Longitude.	Limits of Latitude.	Breadth.	Region.	No. of Drawings. M. L.	M. S.	B. S.	G.M. S.	To[tal]
1	310° to 10°	+60° to −60°	60°	Sinus Sabæus	11	10	4	1	2
2	10 „ 70	+60 „ −60	60	Mare Acidalium	10	11	2	0	2
3	70 „ 120	+60 „ −60	50	Lacus Solis	9	13	...	...	2
4	120 „ 180	+60 „ −60	60	Mare Sirenum	8	9	1	...	1
5	180 „ 250	+60 „ −60	70	Mare Cimmerium	3	8	1	...	1
6	250 „ 310	+60 „ −60	60	Syrtis Major	7	5	2	...	1
7	0 „ 360	−60 „ −90	360	S. Polar Region	...	...	...	...	...
8	0 „ 360	+60 „ +90	360	N. Polar Region	48	56	10	1	11

In the above table the letters M., B., and G.M. at the head of the columns are the initials of the three observers; the letters L. and S. refer to the sizes of the prepared discs upon which the drawings were made, L. denoting the larger discs and S. the smaller.

The six drawings selected for reproduction are the following:

TABLE IV.

Fig.	No of Sketch.	Region.	G.M.T.	d	h	m	Longitude.
1	72	Sinus Sabæus and Mare Acidalium	April	30	1	51	9·0
2	69	Mare Acidalium and Lacus Solis ...	„	27	4	17	71·54
3	59	Mare Sirenum	„	19	4	27	145·07
4	51	Mare Cimmerium	„	14	5	13	200·10
5	49	Mare Cimmerium and Syrtis Major	„	7	4	13	246·90
6	45	Syrtis Major	„	2	4	0	287·27

TABLE V.

Index of Names of Martian Details.

1. Pyrrha.
2. Deucalion.
3. Sinus Sabæus.
4. Furca.
5. Edom.
6. Thymiamata.
7. Margaritifer Sinus.
8. Chryse.
9. Typhon.
10. Euphrates.
11. Hiddekel.
12. Gihon.
13. Oxus.
14. Indus.
15. Jamuna.
16. Protonilus.
17. Deuteronilus.
18. Niliacus L.
19. Lunæ L.
20. Dioscuria.
21. Arnon.
22. Cydonia.
23. Acidalium M.
24. Tempe.
25. Ortygia.
26. Tanais.
27. Thaumasia.
28. Nectar.
29. Solis L.
30. Tithonius L.
31. Phœnicis L.
32. Ganges.
33. Chrysorrhoas.

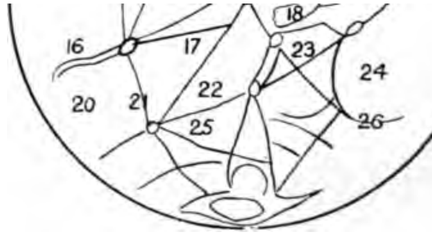

16
17
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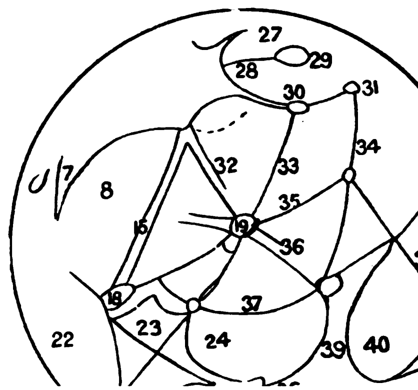
Fig. 1.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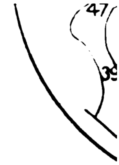
22

Fig. 1.—1903 APRIL $30^d\ 1^h\ 51^m$ G.M.T.
Reference No. 72. Powers, 375, 450.
$\lambda = 9°\!\cdot\!08$; $\phi = +24°\!\cdot\!7$; $a = 13''\!\cdot\!11$.

Fig. 2.—1903 APRIL $27^d\ 4^h\ 17^m$ G.M.T.
Reference No. 69. Powers, 375-700.
$\lambda = 71°\!\cdot\!54$; $\phi = +24°\!\cdot\!6$; $a = 13''\!\cdot\!37$.


47

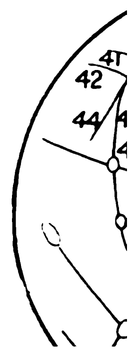

42
44

Fig. [illegible]

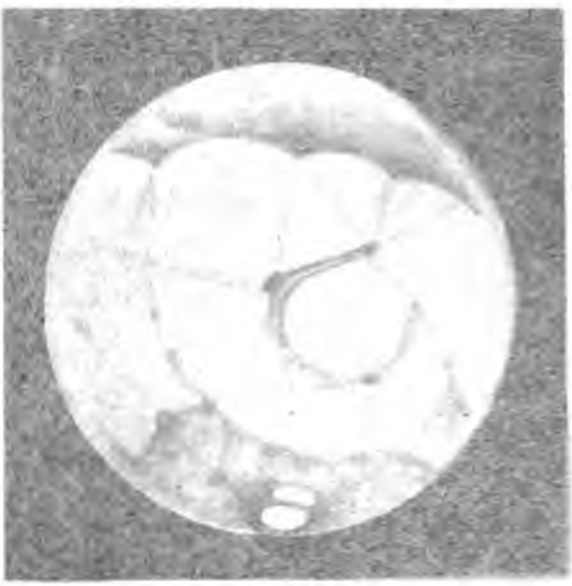


Fig. [illegible]


42
44
45
49
61

Fig. 3.—1903 APRIL $19^{d}\ 4^{h}\ 27^{m}$ G.M.T.
Reference No. 59. Power 450.
$\lambda = 145^{\circ}{\cdot}07$; $\phi = +24^{\circ}{\cdot}01$; $a = 13''{\cdot}97$.

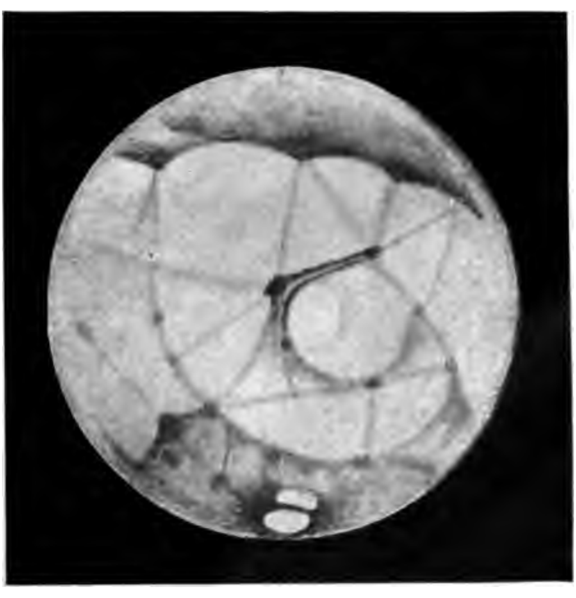


Fig. 4.—1903 APRIL $14^{d}\ 5^{h}\ 13^{m}$ G.M.T.
Reference No. 51. Power 450.
$\lambda = 200^{\circ}{\cdot}10$; $\phi = +23^{\circ}{\cdot}8$; $a = 14''{\cdot}27$.

KEY MAP.

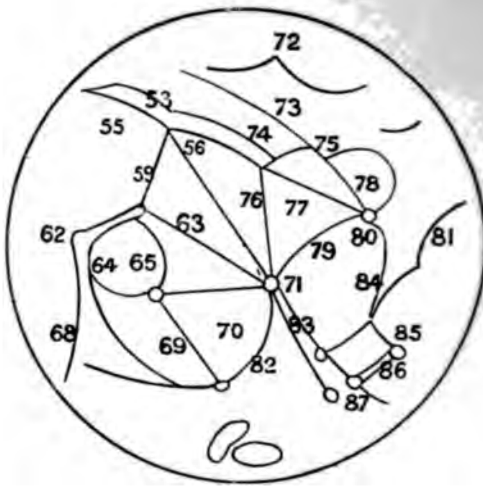


Fig. 5.

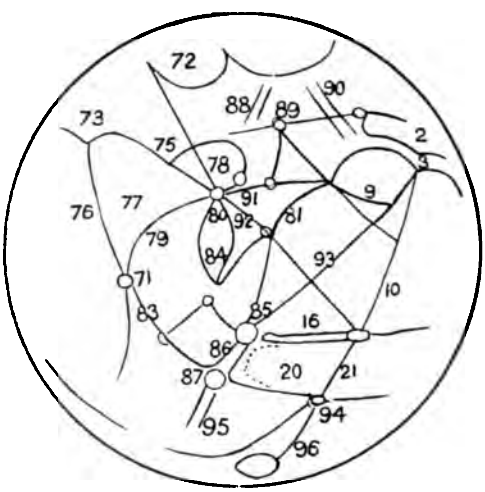


Fig. 6

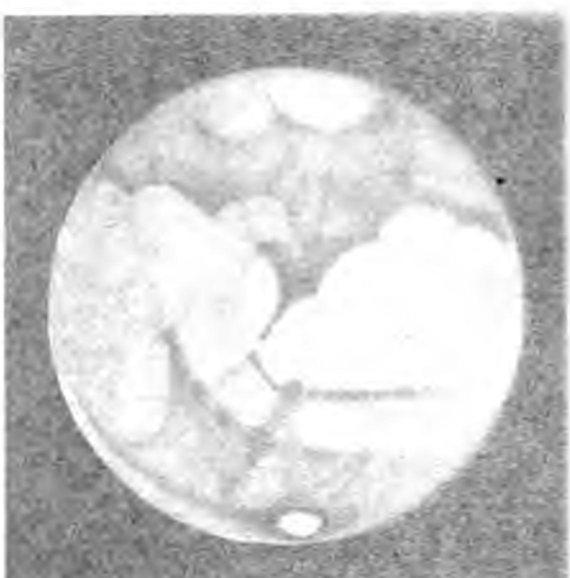


Fig. 6.

Fig. 5.—1903 April $7^d\ 4^h\ 13^m$ G.M.T.
Reference No. 49. Power 450.
$\lambda = 246^\circ{\cdot}90$; $\phi = +23^\circ{\cdot}4$; $a = 14''{\cdot}48$.

Fig. 6.—1903 April $2^d\ 4^h\ 0^m$ G.M.T.
Reference No. 45. Power 450-700.
$\lambda = 287^\circ{\cdot}27$; $\phi = +22^\circ{\cdot}9$; $a = 14''{\cdot}56$.

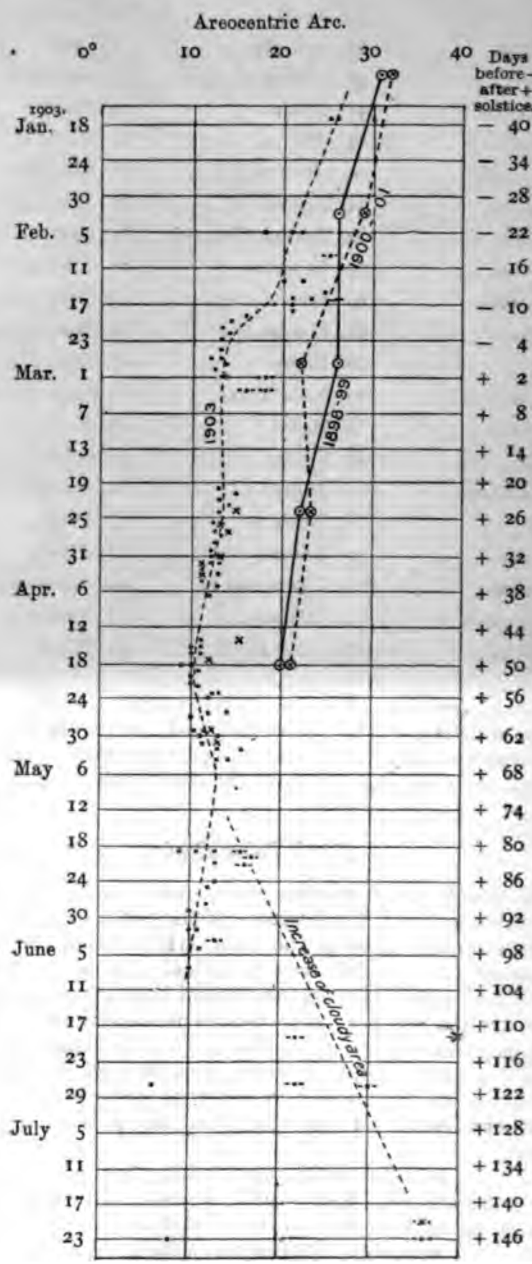
34. Iris.
35. Uranius.
36. Nilus.
37. Dardanus.
38. Phlegethon.
39. Ceraunius.
40. Arcadia.
41. Sirenum M
42. Memnonia.
43. Arduenna.
44. Gigas.
45. Titan.
46. Macrobrius.
47. Mareotis L.
48. Lycaon.
49. Ammonium.
50. Nerigos.
51. Titania.
52. Cebrenia.
53. Cimmerium M.
54. Zephyria.
55. Acolis.
56. Cyclopia.
57. Læstrygon.
58. Antæus.
59. Cyclops.
60. Cerberus.
61. Titanum L.
62. Trivium Charontis.
63. Eunostos.
64. Styx.
65. Elysium.
66. Erebus.
67. Erebi Fons.
68. Hades.
69. Anian.
70. Ætheria.
71. Nubis L.
72. Ausonia.
73. Tyrrhenum M.
74. Hesperia.
75. Syrtis Minor.
76. Adamas.
77. Lybia.
78. Abyssinia.
79. Thoth.
80. Mœris L.
81. Casuentus.
82. Alcyonius.
83. Casius.
84. Nilotis.
85. Coloë Palus.
86. Boreosyrtis.
87. Copais L.
88. Lunæ Pons.
89. Hippus L.
90. Solis Pons.
91. Bubastis.
92. Pallas.
93. Phison.
94. Ismenius L.
95. Pyramus.
96. Kison.

The six drawings (Plates 21–23) illustrate the chief features of the six divisions of the equatorial and temperate zones of the planet during the apparition of 1903; the following section deals with the chief changes noted in the north polar region.

North Polar Region.

The north polar regions were most favourably placed for observation in 1903, the decrease of the polar caps permitting of observation quite close to the pole, while the north latitude of the centre of the disc was practically at a maximum. In Table VI. (Table VII. in manuscript) I have given the areocentric arc subtended by the polar cap as measured off each of the drawings; the diagram gives the same information graphically; and on it I have also plotted the arc subtended by the polar cap at the same Martian season in previous apparitions. No deviation of the centre of the cap from the pole of rotation was detected.

With the melting of the snows white detached spots appeared in the polar shades. The largest, whitest, and most pronounced of these spots was shown first rather indefinitely on February 5. It was steadily seen throughout April, and was very


Areocentric Arc.
0° 10 20 30 40
Days before – after + solstice.
1903.
Jan. 18 – 40
24 – 34
30 – 28
Feb. 5 – 22
11 – 16
17 – 10
23 – 4
Mar. 1 + 2
7 + 8
13 + 14
19 + 20
25 + 26
31 + 32
Apr. 6 + 38
12 + 44
18 + 50
24 + 56
30 + 62
May 6 + 68
12 + 74
18 + 80
24 + 86
30 + 92
June 5 + 98
11 + 104
17 + 110
23 + 116
29 + 122
July 5 + 128
11 + 134
17 + 140
23 + 146
1903
1898-99
1900-01
Increase of cloudy area

distinct in May and early in June, after which it appeared to become merged in the haze which overspread the region. As a rule it was an elongated, curved spot, shaped rather like a carraway seed, concentric with the pole, and at times almost as brilliant as the polar cap. It was separated from the latter by a very dark, narrow, curved line, and also from *Panchaia* by a very dark streak. In addition to the detached spots a white star-disc-like brilliant circular spot was very distinctly seen at the border of the cap on April 27, 29, 30, and May 2.

The history of the polar cap in 1903 may be divided into four stages:

First Stage. From the commencement of the observations to about the middle of February. Cap, bright white, decreasing rapidly; bordered by marshes with no very definite boundary.

Second Stage. From the middle of February to about the first week in June. Cap, intensely white, decreasing very gradually, sharply bounded by an intensely black line shading into the marshes. During this stage the details near the cap were seen with great distinctness; and several detached white spots joined in the shades surrounding it.

Third Stage. From about June 10 to end of July. Disintegration of the cap and formation of a fog-like envelope of considerable extent, sometimes allowing the minute bright nucleus to be dimly seen. The surrounding dark line had either ceased to exist, or become merged in the haze.

Fourth Stage. Disappearance of the cap, which was replaced by a large indefinite very dull lightening of fog or mist, with no definite boundaries. The date of this change cannot be fixed exactly owing to the paucity of the later observations, but was probably some time early in August. This stage appears to have been accompanied by a general fading of the Martian maria. Comparing the behaviour of the polar cap this year with the phenomena in 1898 and 1901, it is apparent that the decrease in area was much more rapid this year, and its diameter at the summer solstice much smaller than in previous years. After the solstice, however, the decrease was exceedingly gradual, and the cap survived with great brilliancy for some time.

In the following table (Table VI.) the areocentric arc subtended by the polar cap on each of the drawings is given. In this table D = the number of days before (−) or after (+) the summer solstice of the northern hemisphere, λ° the longitude of C.M. of the centre of the disc, and a the areocentric arc subtended by the cap.

Figures in ordinary type are those determined from my own drawings; figures in heavy type from drawings by Lieut. Barker (B.) and G. Molesworth, Esq. (G.M.).

In the diagram each dot represents the arc measured from one of my sketches; each cross a measure from Lieut. Barker or G. Molesworth, Esq. Where the cap was indefinite I give three dots, the centre one darkest (thus . ● .).

3 M 2

TABLE VI.

Areocentric Arc subtended by N. P

Date. 1903.	D.	λ°.	α.	Remarks.
		°	°	
Jan. 17	−41	346	30	
	−41	356	26	27°.
	−41	9	25	
Feb. 5	−22	170	21	
	−22	179	22	20°·5.
	−22	188	18	
9	−18	145	25 ±	Rather indefinite.
13	−14	106	22	Rather indefinite,
	−14	115	20	± 22°.
15	−12	79	25	
16	−11	72	23	22°.
	−11	83	21	
	−11	90	± 26	Indef.
17	−10	63	21	20°.
	−10	75	19	
18	− 9	52	21	
19	− 8	44	16	16°.
	− 8	57	16	
20	− 7	31	14	
21	− 6	25	13	13°
	− 6	36	13	
22	− 5	21	12	Small. 14°?
23	− 4	12	13	
24	− 3	2	15	
25	− 2	353	13	
26	− 1	339	12	12°·5.
	− 1	352	13	
27	± 0	336	13·5	Solstice.
28	+ 1	327	12·5	
Mar. 1	+ 2	319	13	
3	+ 4	289	18	Indef. ± 17°.
	+ 4	302	16	
20	+21	41	13	
21	+22	46	15	
22	+23	30	13	Exceedingly white.
23	+24	21	14	

	D.	λ°.	a.	Remarks.
		°	°	
3	+55	110	13	
4	+56	101	12	
6	+58	84	14	
	+58	94	12	
7	+59	71	10	Very white spot at S. end
9	+61	6	11·5	
	+61	23	12	B.
	+61	51	10·5	Very white spot S.E.
0	+62	9	13	
	+62	42	11	Very white spot S. central.
1	+63	349	13	
	+63	0	13	B.
	+63	33	11	
2	+64	26	13	White spot S. central.
	+64	36	16	
4	+66	332	14	Diffuse.
	+66	8	13	
9	+81	182	9	Diffuse, faded.
	+81	190	11	Not very dark.
	+81	235	13	
	+81	247	16	Diffuse.
0	+82	220	17	"
1	+83	162	13	Sharp

Date. 1903.	D.	λ°.	a.	Remarks.
		°	°	
May 21	+83	202	13	Sharp.
24	+86	188	13	"
25	+87	135	12	"
28	+90	132	12	Fairly sharp.
29	+91	95	10	Sharp.
	+91	133	10	Marshes very dark.
	+91	143	10	
June 1	+94	78	11	"
	+94	106	10	Fairly dark.
3	+96	94	13	Rather diffuse
4	+97	45	11	Fairly sharp.
7	+100	20	10	Edge diffuse.
19	+112	297	22	Faint edge very nebulous.
	+112	301	40	**Very diffuse (G.M.)**
27	+120	184	22	Very faint.
	+120	218	30	White central spot ± 6°.
July 20	+143	329	36	**Very diffuse (G.M.)**
23	+146	294	36	White centre ± 8°.
Sept. 14	+199	132	...	Gone.
17	+202	99	...	"

Special Features.

Geminations.—Very few cases of gemination have been seen during the apparition. The following are the most distinct cases.

Boreosyrtis.—Certainly double, April 2–5.

Casius.—This marking is certainly not a canal in the true sense of the word, but merely a darker knotted edge to shaded Utopia. It was certainly anomalously double in the early part of April.

Cerberus.—This marking appears to be really allied to the narrow *maria*. Certainly double on April 14.

Nilosyrtis (*Nilotus*).—Certainly double April 4 and 5. Components very close.

Pierius.—Double at beginning of April.

Protonilus.—Very dark, knotted, and irregular. I cannot regard Protonilus this year as a true canal. In spite of the negative observation of March 1 and April 2, I am inclined to

believe that it was double for a con
apparition, but the irregularity of tl
doubling very difficult to see.

Pyramus.—Doubtfully double on A

I have not considered in the foregoi
cations of *Nilokeras* and *Ceraunius.*
and consist obviously of two distinc
sense true double canals. *Nilus, Gang*
broad with a certain slight appearance
above geminations were best visible in
This may perhaps be due simply to
conditions and the size of the disc, ther

Projections.—The following cases c
1903:—

January 17^d 12^h 04^m G.M.T. A ve
jection, at the limb, position angle $\pm 2c$

February 22^d 12^h 20^m G.M.T. (Pow
a very small projection from the term
($\lambda° = \pm 308°$ ϕ $-25°$ to $-30°$). The
for a short time, but before I could m
became too bright." (Doubtful.)

March 3^d 12^h 35^m G.M.T. (375). N
to project outside curve of terminator.

April 16^d 4^h 35^m G.M.T. (450). Dis
projection on N.W. limb, not far fro
position marked on No. 55. Visible f
the form of a small brilliant circular sp
a minute white mound beyond the limb

May 4^d 4^h 51^m G.M.T. Slight defo
N. of Lunæ L. marked on No. 79. Te
at this point than elsewhere. (Certain

July 23^d 2^h 20^m G.M.T. Slight app
nator just S. of the line Proto-Deuteron
Arabia.)

Twilight at the Terminator.—On sev
apparition I have been much struck
intensity of the twilight shading along
to me this is much greater than is pe
would lead us to expect an atmosphe
Mars than is usually accepted. On th
ness of the darker markings close to
comparative absence of atmosphere e
against such a conclusion. The real
the constitution of the Martian atmosp
that of the Earth.

General Remark

The Importance of Good Air.—I a
vinced of the importance of good air

the study of Martian detail. On some of the glorious nights in March and April this year the appearance of *Mars* is absolutely different from what it is with the same power and seemingly sharp (but not quite perfect) definition. Markings which seem straight uniform streaks under the latter conditions break up into most complex structures under perfect definition, and details can be seen which were hitherto unsuspected. Yet the change in the definition is very slight indeed, merely the difference between "sharp" and "very sharp"; and the untrained eye would scarcely detect it.

These perfect nights are rare, even in Ceylon; but I am satisfied that experience of one or two of them would convince the most sceptical of the objective reality of the majority of the "so-called canals."

Classification of the Details.—I think it is high time that the detail on *Mars* was specialised and classified in something the same way as that of the Moon has been.

At present the details visible on *Mars* may be divided into: (i.) the polar caps; (ii.) the polar "marshes"; (iii.) the maria or "seas"; (iv.) the "continents"; (v.) the "half-tones"; (vi.) the "canals"; (vii.) the oasis or "lakes."

Of these subdivisions (iii.), (iv.), and (v.) grade insensibly into each other, with no rigid line of demarcation. We have every variety of tone from brilliant white areas, such as Argyre and Edom, through half-tones like Hesperia and Deucalion, and heavily shaded areas like Baltia and Utopia, barely distinguishable from the lighter maria, to the almost black tones in the Syrtis Major, Sinus Sabæus, and Mare Acidalium.

Under the heading of "canals" also we have (as pointed out by the Rev. T. E. R. Phillips in *Monthly Notices*, vol. xliv. No. 1, p. 40) several utterly distinct phenomena "lumped together" under one generic name. Large knotted streaks, shaded areas of considerable extent with darker edges, broad uniform smudges, irregular edges to dark areas, slight changes of tone, narrow well-defined streaks, and fine delicate lines at the limit of vision are all impartially claimed as "canals." This is, to say the least of it, unscientific. It should be possible (though I admit not easy) to classify these features in some more satisfactory and scientific manner, and such a classification would do much to simplify the work of investigation. I give a rough idea of the sort of classification I would propose. In this the detail is grouped into the main divisions: (A) continents, (B) maria, (C) "canals" (for want of a better word). The lakes and half-tones occurring in the continents I would group under (B), and the half-tones in the maria under (A). The subdivisions would be somewhat as follows:—

(A) *Continents.*—(1) Bright continental areas partially bordered by very dark maria (*e.g.* Edom, Chryse).

(2) Continental areas bordered by faint edgings, generally representing a slight change of tone (*e.g.* Amazonis, Eden).

(3) Areas bordered by distinct streaks with or without a change of tone (*e.g.* Dioscuria, Cydonia).
(4) Shaded areas bordered by distinct streaks (*e.g.* Titania, Utopia).
(5) Half-tones, generally more or less rectangular in outline, occurring in the maria (*e.g.* Hesperia, Atlantis).
(6) Islands, generally circular or oval in outline, occurring in the maria (*e.g.* Hellas, Argyre, Thyle).
(7) Faint shaded areas with no definite streak edge (*e.g.* northern portion of Thaumasia).

(B) *Maria.*—(1) Large variegated maria of irregular outline (*e.g.* Syrtis Major).
(2 Elongated maria, more or less rectangular in outline, sometimes seen double (*e.g.* M. Cimmerium, Sinus Sabæus).
(3) Detached large lakes, roughly circular or oval in outline (*e.g.* L. Solis).
(4) Detached smaller lakes, roughly circular or oval (*e.g.* Siloë Fons).
(5) Large detached irregular lakes (*e.g.* M. Acidalium).
(6) Small irregular lakes (*e.g.* Oxia Palus [?]).
(7) Half-tones, with darker edgings, occurring in the continents (*e.g.* Ceraunius, Nilokeras).

(C) "*Canals.*"—(1) Large irregular streaks, sometimes double (*e.g.* Cerberus, Protonilus).
(2) Broad diffuse streaks, sometimes double (*e.g.* Jamuna, Gigas).
(3) Narrow uniform streaks (Læstrygon, Gihon).
(4) Narrow uniform lines (the Lowell interpretation of the canals).
(5) Irregular darker edges to half-tones (*e.g.* Casius, Granicus).
(6) Streak edges to half-tones (*e.g.* Pierius, Deuteronilus).
(7) Edges to half-tones, with no definite darker streak (*e.g.* Poros, Cantabias).

Some such classification as this would immensely simplify the consideration of the markings on *Mars*. In many cases the different classes would merge insensibly into each other, in which case I would suggest giving the two subdivisions connected by a hyphen (*e.g.* Cerberus might be classified as B_2-C_1).

The Gemination of the Canals.—The gemination of the canals of *Mars* does not, after all, appear to be such a miraculous phenomenon. I must admit that I do not understand a narrow uniform line with the "oases" on it suddenly becoming widely double; the companions lying some distance on either side of the position of the single canal, and each being a faithful replica of the original with all its uniformity and all its knots. Is this, however, a fair account of the phenomenon of gemination as it usually appears to most eyes?

Speaking for myself, I would say "Certainly not." The cases

of gemination I have seen on *Mars* have usually occurred in subdivisions C_1 and C_2 of the above classification. In the first of these classes the phenomenon, as already pointed out by Maunder in 1892, is strongly analogous to the lightenings which appear in the centres of the narrower maria (class B_2) (*Mars Report*, B.A.A., 1892, p. 197). In the second class the "canal" under all but the best definition appears a broad uniform streak; but, when the seeing is at its best, this streak is found to be bounded along either side by slightly darker lines. There is no sudden shift in position of either component, and the gemination generally occurs in the coarser, not the finer markings. I cannot see in this any tendency of the canals to "jump with magical fissiparity at distances of 300, 400, or 500 miles." Such phenomena may occur, but I have never seen them in the course of several years' careful study of *Mars*.

A peculiarity of *Mars*, which has been little noticed, may throw light on the question of gemination. I refer to the strong parallelism which undoubtedly exists in many regions between different canals. Several such parallel sets can easily be mentioned: *e.g.* Iris, Sirenium, Titan, Læstrygon, Cyclops, Amenthes; Araxes, Gorgon, Brontes; Tartarus, Antæus, and other instances too numerous to mention.

Two such parallel canals with a slight included shade, if close together, would at once give the appearance of gemination. If only one canal, or the faint included shade alone, was seen, the canal would certainly be noted as single. This would explain the apparent anomaly of a canal being seen narrow and single, broad and single, and nearly doubled by different observers at the same time. In the first case only one of the bounding canals would be seen, the fainter one and the included shade being missed; in the second only the included shade with no darker edgings is seen; whilst in the third the included shade would be missed and only the darker edgings detected.

Reality of the Canals.—Personally, I am quite convinced of the reality of the great majority of the so-called canals; I think I could have convinced the most sceptical on this point if they could only have spent an hour or two at my telescope on some of the perfect nights in March and April this year. I do not mean to say that the fainter ones exist exactly in the form in which we see them. They are, to quote Mr. Maunder, "the integration of markings far too small to be separately defined." As in previous years, even the fainter ones appear to me to have evidence of structure. They are "streaky" not linear, the "streaky" appearance being most distinct when the definition is best. They are more like a streak made on very rough paper with a round-pointed crayon or stump than an ink-line drawn with a pen. The Læstrygon is, I think, the most uniformly linear of them.

Detail in the Maria.—This year I have had the opportunity of carefully studying two of the larger maria (the Mare Acidalium

and the Syrtis Major) under practically perfect conditions. From the results of this study I am convinced that the nature of the delicate detail is the same all over the planet. The edges to the maria are as a rule canaliform objects, of the classes C_5, C_6, and C_7. There are in the maria the same delicate streaks; similar to, and in continuation of, those in the continents, with darker lakes at the points of intersection. The only difference is in the tone of the background on which the details are seen. Naturally they are more easily detected on a light background than on a dark one. The canaliform edges of the maria and the "canals" traversing them are almost always in prolongation of the continental "canals," and are obviously connected phenomena.

Illusion and Contrast.—Experiments by Maunder, Lane, and others in the last few years with artificial discs have suggested the possibility that the canals are in some cases illusions. These experiments have been interpreted by some as clearly proving that all the canals are illusions; but this conclusion is not warranted by the experiments. Wherever a non-existent canal is drawn, there are always (to quote Mr. Maunder) "a few minute markings much too small to be seen individually," a crease in the paper, or a slight change of tone. In other words, the detail is there, but beyond the resolving power of the eye, which consequently translates it into the simplest form.

But where does reality end and illusion begin? It is absurd to attribute markings like Cerberus, Ganges, Nilosyrtis, and Agathodæmon to illusion. They are as incontestably real as the belts of *Jupiter*, and when well placed are ridiculously easy objects on anything like a good night, even with comparatively small apertures. Is it not reasonable to suppose that the employment of larger apertures (within limits) and higher powers, in good air, will reveal similar but more delicate details quite as real as these; and that careful study of the planet will add to their number? In this case the illusion theory need only be invoked to explain comparatively few cases out of a very large number.

The contrast theory brought forward lately by M. Antoniadi is plausible, and may be held to explain some of the delicate details on *Mars*. But if pressed to extremes it becomes a most dangerous argument. If we carry it to its logical conclusion we shall have a *Mars* deprived of all "nuances" of light and shade, both light and dark markings being broad masses of uniform tone unrelieved by any half-tones or delicate shading. But its most dangerous tendency is in exalting hurried sketches of *Mars* to a higher level of accuracy than drawings based on careful and extended study of the planet, as, according to the contrast theory, these conditions tend to strain the eyes and produce illusion.

Up to date, all experienced planetary observers have insisted on the importance of prolonged and persistent study. If we carry the contrast theory to excess, however, all this is wasted time. The careful series of drawings made under such conditions

will be so vitiated by eye fatigue and the effects of contrast as to be useless as contributions to our knowledge of the planet.

The expert observer is far better off than the tyro in one respect. He will have much less difficulty in discriminating between reality and illusion.

The illusive doublings, for instance, produced by inferior definition, wrong focus, or fatigue of the eye are so patent to the expert, that they lose all power to deceive. This necessary experience can, however, only be gained by prolonged study.

If the majority of the delicate details on *Mars* are simply due to contrast, the same explanation should hold good with many coarser details on the other planets.

Let us apply the contrast theory to the detail on *Jupiter*, which presents some points of resemblance to that on *Mars*. We might say that the darker edgings of the equatorial belts, the brighter spots bordering them, the longitudinal white rifts in these belts, and the duplicity of the fainter belts are all producible by contrast. Possibly they are, but it does not follow that they are so produced. On the other hand most of these phenomena are incontestably real, and are even shown on some of the imperfect photographs which have been made of the planet.

Are we then justified in assuming their reality in the case of *Jupiter*, while we ascribe the very similar phenomena seen on *Mars* entirely to contrast?

If we could use a power of 3000 or 4000 on *Mars* efficiently, I think we should find that many of the details ascribed to illusion or contrast are realities. The larger image would enable us to break up the detail into recognisable forms. The geometrical and linear forms which the markings of *Mars* assume to many eyes merely result from the minuteness of the component details, and the inability of the eye to grasp their real nature.

NOTE.—*The report of his observations of Mars in* 1903 *presented to the Society by Major P. B. Molesworth, from which the preceding paper has been extracted, was too long for reproduction in full in the "Monthly Notices." The Council felt, however, that no mere abstract would satisfactorily set forth the great amount of work on the details of the planet which the report represented, and decided, therefore, to place the complete manuscript in the Library, where it will be at all times available for consultation and reference, and to print only the chief tables and general conclusions which Major Molesworth has given.*—THE SECRETARIES.

On the Relative Efficiency of Different Methods of Determining Longitudes on Jupiter. By A. Stanley Williams.

The proof of Professor G. W. Hough's further paper on this subject has been read with much interest by me, as it defines his position more clearly with regard to several questions at issue. My remarks on his paper will be considered under four heads—namely, (1) The apparent or accidental errors of the observations; (2) Systematic error; (3) The theoretical side of the question; and (4) Application to the planet *Saturn*.

(1) *The Apparent Errors of the Observations.*

My first paper on this subject, published in the *Monthly Notices*, 1904 March, was entirely confined to the question of the apparent or accidental errors of observation; all consideration of systematic error, which includes both "personal equation" and what has been termed "variable error," having been purposely excluded. And it has now, I should imagine, been firmly and incontrovertibly established that when a large mass of observations by the micrometric method are compared with a correspondingly large series by the method of transits in exactly the same manner, the apparent errors of the observations are for all practical purposes the same with either method. With both methods the average mean error of an observation is $\pm 2^{m}\cdot 0$ for spots in general, this value being reducible to $\pm 1^{m}\cdot 5$, or less, under exceptionally favourable circumstances.*

There is not very much in Professor Hough's present paper bearing directly on this subject. He states that he finds the mean error of Schmidt's observations to be $\pm 2^{m}\cdot 65$ when they are reduced with a variable increasing rotation period. It is necessary to point out, however, that this result still cannot be accepted as comparable with any of the similar data contained in my writings, for the reason that the variable increasing rotation period is not the one satisfying Schmidt's observations, but that derived from Professor Hough's own measures.

And apparently this is considered to be a fair way of comparing the results obtained by the two observers! I propose to return to this manner of deriving the apparent errors of observation later on. It should also be remarked that the existence of Schmidt's "constant error," varying with the planet's hour angle, has not in any way been disproved. All that has been done is to show that, as I had anticipated, the apparent errors of Schmidt's

* To my mind it is much more important to know what are the apparent errors of the observations for spots in general than it is for those made under exceptionally favourable circumstances. The mean error for the five spots with a "large number of observations" (see *Monthly Notices*, vol. lxv. p. 171) observed by Professor Hough with the micrometer is $\pm 2^{m}\cdot 5$, which is distinctly larger than the $\pm 2^{m}\cdot 0$ found for the mean error of an observation by the method of transits for the same class of spots.

uncorrected observations are considerably lessened when the latter are reduced with a variable increasing rotation period, even with one not satisfying the observations in question in the best possible manner.

But in forming an opinion as to the accordance of Schmidt's observations it is important not to overlook his earlier results. His twelve observations of a dark spot in 1862 show a mean error of $\pm 0^{m}\cdot 6$; his six observations of a sharp elbow in the same year one of $\pm 3^{m}\cdot 0$; and his five observations of a white spot in 1866 one of $\pm 1^{m}\cdot 2$. The mean of these three results is $\pm 1^{m}\cdot 6$, which is practically the same as that given by the best micrometer observations, and considerably smaller than that shown by his latest work, at any rate as regards the uncorrected observations. And this leads to the question whether there may not be some reason for the apparent errors of these latest observations being perhaps a little large should his "constant error" on a proper discussion prove to have no existence. No one can possibly have a more profound respect and admiration for Schmidt and his work than the writer. Nevertheless it must be remembered that these latest observations were made when he was seventy-five years of age, and the work is one in which quickness of perception probably plays an important part. It has been necessary to go into this matter of Schmidt's observations more deeply than I should have wished, because Professor Hough apparently pins his faith solely on the later observations of this illustrious observer alone. But surely this is not reasonable now that we have so much additional work by many other well-known skilful observers available for purposes of comparison!

Dr. O. Lohse states, I think,* that the probable error of his central meridian transits is $\pm 2^{m}$, although these, as has already been pointed out, were sometimes made with the help of a micrometer and sometimes without, and therefore do not form a perfectly homogeneous series of observations. It should be repeated that the mean error of Schmidt's corrected observations is only $\pm 1^{m}\cdot 5$. The following additional data may be added for comparison with those contained in the list on pp. 433, 434 of the *Monthly Notices* for 1904 March. Nine observations of the red spot by Mr. W. F. Denning in 1883 show a mean error of $\pm 2^{m}\cdot 3$ (*Astronomical Register*, vol. xxi. p. 172).† Ten observations by the same observer in 1904–5 October to March give one of $\pm 1^{m}\cdot 2$ (*Observatory*, 1905, p. 188). Fifteen observations of the red spot hollow by the Rev. T. E. R. Phillips in 1904 give a mean error of $\pm 1^{m}\cdot 5$ (private letter). Nine observations of the middle of the red spot in 1903–4 by the

* I have mislaid the part of the Potsdam Observatory *Publications* containing his results, so that I am unable to verify this figure or to work out the actual mean errors of his observations.

† Really rather less, for the ephemeris does not satisfy the observations well.

writer show a mean error of $\pm 1^{m}\cdot 5$; and ten of the following en show one of $\pm 2^{m}\cdot 1$ (*A. N.* 3983). Twenty-five observations (no yet published) of the middle of the red spot by the writer durin the past opposition give a mean error $\pm 1^{m}\cdot 5$. The mean o these six additional results is $\pm 1^{m}\cdot 7$, practically the same a that found before.

The real rotation period of a spot is never known, and the onl fair way in which we can form an idea of the accidental error entering into a determination is to compare the observations o any particular observer with an ephemeris satisfying the motio of the spot *according to the observations of that observer.* In almost all astronomical problems we are confronted with th same difficulty, and I believe I am right in saying that it is th universal custom to derive the mean or probable errors in an particular investigation from the accordance of the observation *inter se.* It must be remembered that we are here dealing onl with the apparent errors of observation, not with the systemati errors. Yet Professor Hough has derived the apparent errors o the observations made by one observer by comparing them wit an ephemeris derived from the observations of another observer That is, he takes an ephemeris which necessarily satisfies in th best possible way his own observations. A method more advan tageous to the micrometrical method and more obviously unfai to the method of transits it would be difficult to imagine.

(2) *Systematic Error.*

That the micrometric method is free from all kinds o systematic error has most certainly never been proved. A few no doubt accidental instances of more or less close agreement with the Marth-Crommelin ephemeris, or with this ephemeri "corrected to conform to the *true* * rotation period," cannot be held to prove it. It would not be difficult to adduce cases o equally satisfactory agreement on behalf of the method o transits. For example, Professor E. E. Barnard's observation of the red spot in 1891 (*Monthly Notices*, vol. lii. p. 12) agre excellently with the ephemeris of Marth—far better, in fact than do the micrometer observations of 1887 in the instanc referred to by Professor Hough. On the other hand, there i no difficulty in selecting cases where the micrometer observa tions show, from internal evidence, clear signs of being subject to systematic error. Professor Hough admits that he has t "correct" the Marth-Crommelin ephemeris before his observa tions (of the red spot?) can be made to conform to the same and he also admits that he not infrequently has to use a variable rotation period, sometimes even one with three terms But in making these admissions it seems to me that he simpl cuts the ground from under his feet, for by similarly "correcting"

* *I e.* the rotation period satisfying Professor Hough's observations

the Marth-Crommelin or any other ephemeris,* or by making use of a suitable variable rotation period, the majority of the errors that have been designated as "variable errors" or "cumulative errors" can without difficulty be accounted for or corrected. Hence these admissions really prove that the micrometric method is itself liable to the same systematic errors! Certainly the variations thus corrected in the micrometer observations are in several cases exactly of the same apparent character as those to which the method of transits is subject, and which have been referred to as "variable errors" or "cumulative errors."

Several instances of large variable or systematic errors affecting the micrometric method have been already pointed out. As another example, I would now invite serious attention to the following figures, given in the "Report" of the Director of the Dearborn Observatory for 1885, p. 13, as the variable rotation period deduced for the red spot in 1884–5:—

							h	m	s
1884	Sept.	25	to	Dec.	3	Rot. per. =	9	55	44·0
	Dec.	3	„	Feb.	2		9	55	40·1
1885	Feb.	2	„	April	4		9	55	39·1
	April	4	„	May	15		9	55	38·7
	May	15	„	June	29		9	55	42·0

Since we read that the motion of the spots on *Jupiter* is "smooth, never abrupt," and that abrupt motion is denied, above all in the red spot, it is evident that the remarkable differences here shown cannot be regarded as real. Hence, to quote Professor Hough's own words, slightly modified: † "Here we have apparently a well-established fluctuation in the rotation period of 5·3 seconds (shown by the micrometer measures) which did not exist"! As the red spot is stated to have become more conspicuous, "so much so as to be readily seen with moderate optical power," it is clear that the foregoing remarkable fluctuations cannot be ascribed to the faintness of the spot.

The following statement seems open to argument. "The objects that are observed are usually many millions of miles in area, and presumably have mass. We should not expect any abrupt change in direction or mode of motion in a moving mass." But what reasons have we for presuming that the spots in general have any (considerable) mass? The inference rather is, it seems to me, that the surface density of the planet is probably slight. Moreover, it does not necessarily follow that a given change is due to an actual transference of matter. Many of the known changes on *Jupiter* are possibly only apparent, and attributable rather to the effects produced by the condensation and expansion of vapours and gases, to convection currents, or to comparatively slight changes of brightness or reflecting power. It is

* Including that which satisfies the micrometer observations.

† *Monthly Notices*, vol. lxiv. p. 828.

well known, too, that very sudden and very considerable chang do sometimes occur on *Jupiter*.

Professor Hough's explanation of his discordant observatio of a white spot in 1881 hardly seems to me sufficient; b assuming it to be so, is not this explanation a tacit admission the validity of my contention as to one way in which "varial error" may arise? "The apparent displacement was simply d to the different reference point in making the measures." Tl is just what I have been endeavouring to point out is a freque source of origination of systematic error with the method transits.*

The position with regard to the whole matter of systemat error may be summed up as follows. The published micromet observations and results possess ample internal evidence showi that they are subject to most if not all of the systematic erro to which the method of transits is liable; besides being, perha also subject to other errors peculiar to the use of the micromet At present we have nothing definite to guide us as to the relati size of these errors, nor can we have, so far as I can see, unt we possess comparable contemporaneous series of observatio with the micrometer by several different observers, such observe working quite independently at distant stations, and using tel scopes ranging in aperture from, say, 6 inches up to 18 inche Professor Hough is therefore not justified in treating all, or eve the larger part, of the differences found to exist between h micrometer observations and those of other observers, made b the method of transits, as being wholly due to the latter metho

(3) *Theoretical.*

This side of the question has not, I think, been treated quit fairly by Professor Hough. It is no very difficult matter t compute the shift in seconds of arc of a point near the centre o a planet's disc due to rotation in a given interval of time. Fo the present purpose use has been made of a convenient formul published by Professor F. L. O. Wadsworth in the *Observator* 1897, p. 369, viz.

$$\epsilon = \frac{21600}{M} \cdot 0{\cdot}00029 \cdot \delta$$

where ϵ is the angular shift in seconds of arc of a point near th centre of a planet's disc per minute, M is the time (in minute of axial rotation, and δ the apparent angular semi-diameter (i seconds of arc) of the planet.

It is necessary to decide upon the diameter of the planet t be adopted. The equatorial diameter of *Jupiter* may vary durin the observable period from 50″ to about 30″. The diameter w ought to adopt, however, is that diameter which corresponds t the distance at which the average of the whole number o

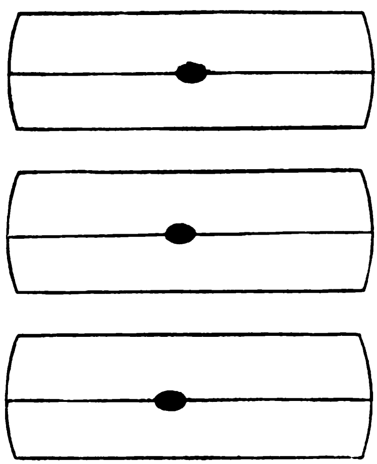
* See *Monthly Notices*, vol. lxv. p. 177.

observations is made. Probably at least three-fourths of all observations are made within the period comprised between two and three months preceding opposition and the two or three months following the same. Likewise the great majority of all spots observed are situate within 20° of the planet's equator, so that the reduction in scale due to latitude will, on the average, be small. Consequently 40″ would seem to be a fair diameter to adopt as that at which the observations are made. For short intervals of time, such as five to ten minutes, the shift of a spot near the planet's central meridian due to rotation may be assumed to occur at a uniform rate. The rotation period of the planet we may take to be $9^h\ 55^m$. Using, then, the above data the average shift of a spot near *Jupiter's* central meridian in one minute of time will be $0''\cdot21$; in five minutes it will be $1''\cdot05$; and in ten minutes $2''\cdot1$.

A

B

C



In order to show the effect of this displacement, the three accompanying figures have been drawn as carefully as possible to scale. They represent the rotational displacement of a spot on *Jupiter* three seconds in length. Fig. A shows the spot in mid-transit, fig. B when it is five minutes past transit, and fig. C when it is ten minutes past transit. I believe that most of those who will carefully examine these diagrams will agree with me in concluding: (1) that an experienced observer should be able to observe the transits with an average mean error of $\pm 2^m\cdot0$; (2) that under very favourable circumstances such an experienced observer should be able to observe the transits with an average mean error of $\pm 1^m\cdot5$, or even less; (3) that an apparent shift or error of central meridian amounting to as much as five minutes is altogether out of the question, much more so is one of ten minutes or more, as we are asked to believe (it is

hardly likely that it could amount to more than a minut (4) that, provided the spot is well defined, there is no rea why the disc should not be bisected by it with as much accur as by a micrometer wire. If the spot were ill defined or irreg in shape, then the measures made of it would naturally suffer the same degree as the bisection of the disc by the spot itself.

As corollary to the foregoing it may be concluded that, si an apparent shift or error of central meridian amounting to m more than a minute is inadmissible, the known displaceme coming under the description of "variable error," "cumulat error," "personal equation," and "variable personal equatio cannot be accounted for by any such hypothesis. In other wo this means, it seems to me, that the cause of the errors in qu tion, or at any rate the larger part of them, must necessarily ascribed to something else, namely, to the different manner which different observers observe the same planetary marking Consequently micrometer measures by different observers wo necessarily be subject to all and the same kinds of systema error. And, further, it follows that all the statements and figu so far as they are correct, contained in Professor Hough's pap respecting the amount and the nature of the systematic err affecting the method of transits will apply, and in all probabil with like force, to the micrometric method. That this is the ri way of regarding the matter is shown clearly by Profes Hough's statement that the "fictitious central meridian chos for any group seems to be accidental, since for different sp observed on the same night the central meridian is different." would be difficult to find a more convincing proof that the sy tematic errors in question are not ascribable to the choice of "fictitious central meridian," but are inherent in or connect with the appearance of the spots themselves. It is also easy imagine the conditions under which the "cumulative error" m

* The analogy drawn by Professor Hough between the transit of a Jovi spot and that of a star over an imaginary wire bisecting the field of a tran instrument, from which the real wires are supposed to be removed, hard seems to the writer to be a happy one, because the distance to be bisect would be many times larger in the latter case than in the former. A bett illustration would be to separate the wires of a micrometer by 40" a observe the time when a star is exactly in mid-transit between the two. should imagine that an observer, after a little practice, could observe su times with a very high degree of accuracy. The only advantage the micr metric method would seem to have is the power of repetition; but th appears to be counterbalanced by the uncertainty in setting on the limbs, a the prejudicial effect caused by placing a wire over a spot.

† Or the same observer at various times and under different circumstanc I fancy that practically everyone who has ever undertaken the work comparing and discussing observations and drawings, not merely of *Jupit* but those of other planets, will be in agreement with the writer as to t sufficiency of this cause to produce the known variable and other systema errors. It must not be forgotten that the appearance of a spot is *large* dependent both on the size of the telescope used and on the state of t seeing, quite apart from any question as to the personal idiosyncrasies of t observer.

arise, but it is almost inconceivable that an observer could unconsciously select a "fictitious" central meridian for a particular spot differing progressively and in a regular manner with the time from the true central meridian, and yet not applying to neighbouring spots observed on the same nights. But we have still more positive proof, if such were required, that these variable and other systematic errors cannot possibly be due to the selection of a "fictitious" central meridian. For when the transits are observed with the help of a micrometer wire, set to half the measured diameter of the disc, these errors occur just the same.

(4) *Application to Saturn.*

It has been shown that the average angular shift of a point near the central meridian of *Jupiter's* disc per minute is $0''.21$; and also that the average mean error of the micrometer observations is $\pm 2^m$, corresponding to a shift of $0''.42$. If we assume the equatorial diameter of *Saturn* to be $18''.6$, and the time of rotation to be $10^h\ 30^m$, we shall get $0''.092$ as the shift per minute of a point on the planet's equator. The spots observed on *Saturn* in 1903 were in a rather high latitude, however. The measures for latitude appear to be somewhat discordant, but probably we shall not be far out if we take it to be $+36°$. The ellipticity of the disc complicates the matter, but multiplying $0''.092$ by the cosine of the latitude we shall get $0''.074$ as the corresponding shift per minute of a spot near the central meridian of *Saturn's* disc in latitude $36°$, $\pm 2^m.0$, and this will be quite near enough. Since the average mean error expressed in arc of the micrometer measures on *Jupiter* is $\pm 0''.42$, a shift of equal amount on *Saturn* in latitude $36°$ will correspond to 5.7 minutes of time in observing the transit. This, then, is the average mean error that Professor Hough's measures of the white spots on *Saturn* might be expected to have. Under very favourable circumstances a somewhat smaller value might be anticipated, but it will hardly be seriously contended, I should imagine, that the spots on *Saturn* were as well suited for measurement as the great red spot on *Jupiter* was at the time of its greatest plainness. It may be taken, therefore, that $5^m.7$ is a minimum value, and it might be nearly twice as great, judging from the micrometer measures of certain Jovian spots. If, therefore, the few micrometer observations of the spots on *Saturn* show a mean error much smaller than $\pm 5^m.7$, such accordance must assuredly be fictitious. This is the case, and such small mean residuals as $\pm 2^m.3$ and $\pm 0^m.8$ are certainly fictitious, as likewise must be any conclusion regarding the variable motion of one of the spots, based on the scanty given data. It may be mentioned that the mean error of an observation by the method of transits of the principal spot from twenty-eight observations discussed by Professor H. C. Wilson * is $\pm 7^m.8$. This is somewhat larger than the theoretical value,

* *Popular Astronomy*, 1903, p. 445.

but this might be expected, seeing that the observations were made by quite a large number of observers, and the spot was certainly more difficult to observe than the average Jovian spot. Mr. Denning has amply explained the reason for some of the larger discordances in the *Monthly Notices*, vol. lxiv. p. 242.

It would be interesting to apply these and some other considerations to the planet *Mars*, and to the case of a fictitious planet of the same size and at the same distance as *Jupiter*, but rotating in half the time that the latter does; but this must be deferred.

Hove: 1905 *June* 5

Addendum to "Discussion of the Greenwich Observations of the Satellite of Neptune" in Monthly Notices, Vol. LXV., pp. 570–583, *by Messrs. Dyson and Edney.*

1. It should have been stated that the quantities $s \sin dp$ and ds dealt with in this paper are in the sense "Tabular—Observed," and the resulting values of da, dN, &c., are subtracted from the tabular places to give the results of the observations.

2. On p. 581, although the result is not affected, it would have been more correct to compare the values of N and I found at Greenwich for 1903·1 with the actually observed values found by Dr. Struve for 1890·3, instead of with the values found from the interpolation formula he derived from a discussion of his own and previous observations. The figures are

H. Struve	...	1890·4	$N = 185^\circ.27$	$I = 119^\circ.16$
Greenwich	...	1903·1	$N = 187^\circ.58$	$I = 117^\circ.40$

In 12·7 years $dN = +2^\circ.31$, $dI = -1^\circ.76$; and the annual changes of N and I are

$$dN = +0^\circ.182 \text{ and } dI = -{}^\circ.138 \text{ for } 1896.7.$$

Dr. Struve's result for 1874·0 being

$$dN = +0^\circ.148 \text{ and } dI = -0^\circ.165.$$

For the mean date 1896·7

$$\psi_2 = 40^\circ.9 \text{ and } \sin \gamma d\theta = {}^\circ.212$$

giving

$$1896.7 \quad N = 186^\circ.44 \quad I = 118^\circ.28 \quad \psi_2 = 40^\circ.9 \quad \sin \gamma d\theta = {}^\circ.212$$

to compare with Dr. Struve's result,

$$1874.0 \quad N = 182^\circ.78 \quad I = 121^\circ.99 \quad \psi_1 = 52^\circ.6 \quad \sin \gamma d\theta = {}^\circ.208$$

The close agreement of the determinations of $\sin \gamma d\theta$ is satisfactory.

The figures on p. 581 should be replaced by

$$N_1M_1 = 52^\circ\!\cdot\!6 \qquad N_2M_2 = 40^\circ\!\cdot\!9 \pm 2^\circ\!\cdot\!5$$

$$M_1N_1N_2 = 121\cdot99 \qquad M_2N_2N_1 = 61\cdot72$$

and $$N_1N_2 = 3^\circ\cdot66$$

Solving the triangles, the values found for the inclination, &c., are the same as those previously given.

3. The inclination of *Neptune's* equator to the plane of its orbit derived from these figures is about 29°.

The Meteors from Biela's Comet. By W. F. Denning.

Undoubtedly the rich shower of *Andromedids* visible in the light of the nearly full moon on 1904 November 21 formed the most important meteoric event of the past year. The only observer of it in the United Kingdom appears to have been the Rev. W. F. A. Ellison, of Enniscorthy, who at $7^h\ 25^m$ G.M.T. saw eight meteors in fifteen seconds, and twenty-four altogether between $7^h\ 25^m$ and $8^h\ 25^m$. Twenty-two others were observed between $8^h\ 25^m$ and $9^h\ 25^m$, after which the numbers "fell off greatly." The radiant by eye estimation from forty or fifty tracks was at $21^\circ + 50^\circ$. The meteors generally were very brilliant, with trains, and a few of the more conspicuous objects were recorded as under :—

1905.	G.M.T. h m		From ° °	To ° °
Nov. 21	8 2	> 1	308 + 47	280 + 39½
„	8 49	♀	Low in W.	Andromedid
„	9 8	♃	337 + 7	329 − 7
„	9 16	♃	354 + 30	348 + 18
Nov. 26	7 35	♀	52 + 27	64 + 8½
28	8 50	> ♀	215 + 50	215 + 46

The display apparently continued until November 28.

It was also observed by K. Bohlin, of Stockholm (*Ast. Nach.* 3997), who says that the radiant of twenty-eight meteors (the paths of which he gives in his paper) recorded on 1904 November 21, 5^h to 11^h (mid-European time) was found by the method of least squares to be about 3° distant from γ *Andromedæ* at

$$26^\circ\ 2' + 44^\circ\ 10'\ (1900)$$

The meteors were of considerable brilliancy. The first

ons of the display were noticed on November 16, a
d to have ceased on November 22.
occurrence of these *Andromedids* (sufficiently bril
ndant to attract special notice in strong moonligh
ble, as there was a rich shower of them in 1899 No
so the interval is only five years, and the inference is
eors are being rapidly spread out along a considerabl
rbit.
observed perihelia of Biela's Comet occurred 1772
and 1852 September 23, so that the mean period de
elve returns is 6·71 years.
great meteoric showers of 1798 December 7 and
er 27 comprise thirteen periods of 6·69 years.
periodic time of the comet in 1846 was 6·617 y
and slightly greater than this according to the comp
verified) returns to perihelion in 1859 May 23,
25–26, and 1872 October 6. By adopting a m
f 6·68 years the observations of the meteoric displ
n fairly well satisfied.

P.P. of Biela. riod of 6·68 years.	Observed Meteoric Display.	Earth's Long. °
52 September 23	...	...
59 May 30	...	...

Schulhof announced that there would occur another serious disturbance in 1901·2 from the same cause. Professor Abelmann, of Vienna, investigated the subject (*Ast. Nach.* 3516), and found that the node would be further affected to the extent of $-6^{\circ}\cdot 2$, altering the shower-date to November 17 at the next maximum return in 1905 (*Observatory*, vol. xxi. p. 399). It appears that in 1901 March *Jupiter* approached the main group of *Andromedids* to within 0·5 of the Earth's mean distance from the Sun.

This particular system, from the shortness of its period, its liability to perturbation, and the great physical changes apparently affecting it, promises to give us a far clearer insight into the phenomena of meteoric streams and their cometary derivations than any other with which we are acquainted. The other prominent showers, correlated with known comets, and forming the *Lyrids*, *Perseids*, and *Leonids*, are probably of more ancient date and certainly of much longer period than the *Andromedids*. Many ages ago the former groups passed through the various gradations resolving them into annual showers with periodical maxima. No doubt, as a comet visible to human eyes, Biela's has vanished for ever. But its disintegration in 1846 and subsequent apparitions in the form of meteoric displays have added much to our knowledge of the subject.

In 1872 the *Andromedids* were confined to one night, and the stream was evidently a compact and narrow one. In 1885 the meteors were visible from November 25 to November 30, and it is probable that the particles are not only spreading out laterally, owing to repeated intersections by the earth, but that the group is lengthening out from year to year along the orbit, and will finally present an annual shower like the *Perseids*. Between the returns of 1892 and 1899 there were seven years, and between those of 1899 and 1904 only five years, so the dispersion of the meteors is evidently considerable.

Professor H. A. Newton pointed out as long ago as 1874 from a comparison of the positions of Biela's Comet at the times of the great showers of 1798, 1838, and 1872 that a "long, extended group of meteoric particles must accompany the comet in its periodic revolution, preceding it to a distance of 300 millions of miles (as in 1838) and following it to a distance of 200 millions of miles (as in 1872)" (*British Association Report*, 1875, p. 224). A further extension has probably taken place in more recent years, but the precise character of the changes effected remains to be determined by future observation.

An interesting point is that the *Andromedids* are now nearly contemporaneous with the *Leonids*. It appears likely that in ensuing years it will be possible to witness two notable meteoric displays in simultaneous action, one yielding objects having the greatest, the other the least, apparent velocity, while the green streaks of the rapid *Leonids* will contrast in a striking manner with the yellow trains of the slowly falling *Andromedids*.

Bishopston, Bristol:
1905 *May* 12.

The most Probable Position of a Point determined from the Intersections of Three Straight Lines. By S. A. Saunder, M.A.

In the course of my work on the Moon I have frequen fixed the position of what may be termed a point of the sec order by measuring its position angles from three points wh coordinates had been well determined. I have shown (*B.A. Memoirs*, vol. vii. pp. 61–65) that when the points are near centre of the Moon's disc, and the distances between them small, the errors involved by neglecting the effects of librat are also small, whilst the reduction of the measures is there much simplified.

In the course of these reductions I have had to consi what was the most probable position of a point so determin I am not aware what is the practice of those who comp meteoric radiants, but a recent writer (*Monthly Notices*, vol. l p. 238) has assumed that the radiant should be placed at incentre of the triangle formed by these lines. As this can correct only under very special circumstances, I have thought might be worth while to call attention to the point.

Supposing the determinations of the lines to be of eq weight, the conditional equations should be so stated that eq residuals are equally probable, and this would seem to be effect at all events in my work, by writing the equations in the fo $x \cos a + y \sin a - p = 0$, so that the residuals represent the p pendiculars from the point finally determined upon the th straight lines. If a distant point were observed with a theodol the equations would require to be differently weighted.

If we use trilinear coordinates, taking these straight lines sides of the triangle of reference, these three residuals will the coordinates α, β, γ of the point, and we have to determi their values so that $\alpha^2+\beta^2+\gamma^2$ may be a minimum.

A necessary condition is that

$$\alpha\delta\alpha+\beta\delta\beta+\gamma\delta\gamma=0 \quad \ldots \quad \ldots \quad \ldots \quad ($$

and $$a\alpha+b\beta+c\gamma=2\Delta \quad \ldots \quad \ldots \quad \ldots \quad ($$

$\therefore$ $$a\delta\alpha+b\delta\beta+c\delta\gamma=0 \quad \ldots \quad \ldots \quad \ldots \quad ($$

From (1) and (3) $$(c\alpha-a\gamma)\delta\alpha+(c\beta-b\gamma)\delta\beta=0$$

and as α, β are now independent this gives

$$\frac{\alpha}{a}=\frac{\beta}{b}=\frac{\gamma}{c}=\frac{2\Delta}{a^2+b^2+c^2} \quad \text{by (2)}$$

If $u\equiv\alpha^2+\beta^2+\gamma^2$ it is easily shown by actual differentiati that

$$r=\frac{\partial^2u}{\partial\alpha^2}=2+2\frac{a^2}{c^2},\quad s=\frac{\partial^2u}{\partial\alpha\partial\beta}=2\frac{ab}{c^2},\quad t=\frac{\partial^2u}{\partial\beta^2}=2+2\frac{b^2}{c^2}$$

and hence that r, t and $rt-s^2$ are necessarily positive, which complete the conditions for a minimum.

The point thus found is the symmedian point which coincides with the incentre only when the triangle is equilateral. It may be constructed graphically from any one of the following properties :

If A B C is the triangle, I the incentre, G the centroid, K the symmedian point, AK, BK, CK, cut the sides in D, E, F respectively, and bc is an antiparallel to BC, so that $A\hat{b}c = A\hat{B}C$.

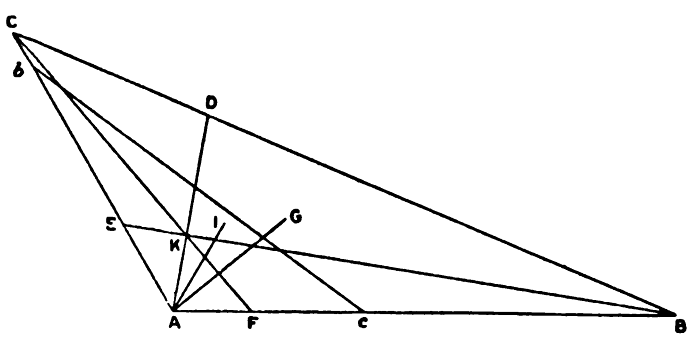
Then $$\text{BD} : \text{DC} :: c^2 : b^2$$

$$\text{AK bisects } bc$$

and $$\hat{\text{I}}\text{AK} = \text{I}\hat{\text{A}}\text{G}$$

with symmetrical relations for the other sides and angles.

This property of the symmedian point is not new, and the only object of this note is to call attention to its bearing upon the problem proposed.



If the determinations of the three lines are not of equal weights, let us suppose their weights to be l, m, n respectively. Then the condition required is that $l\alpha^2 + m\beta^2 + n\gamma^2$ should be a minimum ; whence, as before :

$$\frac{l\alpha}{a} = \frac{m\beta}{b} = \frac{n\gamma}{c} = \frac{2lmn\Delta}{mna^2 + nlb^2 + mlc^2}$$

And in the figure

$$\frac{\text{BD}}{\text{DC}} = \frac{mc^2}{nb^2}, \quad \frac{\text{CE}}{\text{EA}} = \frac{na^2}{lc^2}, \quad \frac{\text{AF}}{\text{FB}} = \frac{lb^2}{ma^2}$$

If the points c, b are so taken that $\dfrac{\text{A}c}{\text{A}b} = \dfrac{n\,.\,b}{m\,.\,c}$, bc is still bisected by AK.

Mr. H. C. Plummer has also pointed out to me that if G be

the centre of gravity of weights l, m, n at A, B, C the ang
IAK, IAG are still equal, thus completing the generalisation
the properties of the symmedian point.

The weights to be given depend, in my work, only on t
numbers of times the directions have been measured. In t
case of meteoric paths they would seem to depend upon t
length of the observed path, its nearness to recognised stars,
distance from the radiant, the persistence of a trail, and possil
upon other causes. K will coincide with I when the weig
l, m, n are proportional to a, b, c.

The Cartesian coordinates of K are easily written down if
remember that a, b, c are proportional to the sines of the ang
between the lines; but the expressions are so long that in practi
I prefer to effect each solution by least squares.

// MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXV. SUPPLEMENTARY NUMBER, 1905. No. 9

The Testimonial to Mr. Wesley.

I have received from Professor Turner the subjoined letter which I think it well should be published in the *Monthly Notices*, as it is self-explanatory, and will, I am certain, be read with interest by the Fellows. The response to the movement so thoughtfully inaugurated by our past President has been most gratifying, and affords ample testimony of the high esteem and regard in which Mr. Wesley is held by those with whom he has been so long and so honourably associated.

I also subjoin a letter addressed to me by Mr. Wesley, which I have great pleasure in publishing.

I feel sure also that I shall be acting in full accordance with the wishes of all subscribers to the testimonial if I tender to Professor Turner hearty congratulations at the success which has attended his action, and thanks for the great personal trouble which he has taken in carrying the matter through.

W. H. MAW.

Professor Turner's letter is as follows :

To the President of the Royal Astronomical Society.

University Observatory, Oxford.

DEAR MR. PRESIDENT,—You will remember that at the beginning of the year I invited a friendly recognition of the thirty years' service which our Assistant Secretary, Mr. W. H. Wesley, had just completed. The suggestion was cordially responded to, and I handed to him at the annual meeting a cheque for £140 on account; but the list was kept open for the benefit

of any Fellows who might through oversight have not yet avai themselves of the opportunity of joining.

As I am now starting for Egypt to observe the Eclipse seems better to close the list definitely. I beg to hand to you account of the sums subscribed, from which you will see that total amount received from the 168 subscribers was £155 9s. The expenses of postage, printing, &c., amounted to £3 14s. leaving a balance of £151 15s., so that I am sending Mr. We to-day a further cheque for £11 15s.

It has been suggested that a list of the subscribers (*names* c and not *amounts*) should be handed to Mr. Wesley, but that bey this it is not desirable to publish any details. I have accordir handed to Mr. Wesley such a list of names together with porti from many cordial letters received—taking particular care to out from the letters any suggestion as to the actual amount s scribed. But should you consider it advisable to publish details, I have placed the material in your hands.

I may add that Mr. and Mrs. Wesley have loyally atten to the suggestion in the circular as regards a holiday. They h been for three weeks in Switzerland and thoroughly enjoyed i indeed, Mr. Wesley is good enough to call it "the finest holi of their lives." I feel sure their many friends will be glad hear this.

Believe me, dear Mr. President,

Yours very truly,

H. H. TURNER

1905 *July* 26.

Burlington House, London, W

DEAR MR. MAW,—I should be very glad if I may be allo the opportunity of thanking the Fellows of the Royal Ast nomical Society for the Testimonial to which they have so fre subscribed.

Mrs. Wesley and I are especially gratified at the gener and appreciative words contained in the extracts from lett which accompanied the subscriptions. I shall always treas these extracts as a testimony of the good will and kindly feel of those with whom my official position has brought me contact.

I should like also again to thank Professor Turner for all trouble and thoughtfulness.

Yours very sincerely,

W. H. WESLEY

1905 August 14.

Latitude Stations in the Southern Hemisphere.

(*Communicated by the Secretaries.*)

In a circular issued by the Central International Geodetic Bureau of date 1905 September, Dr. Albrecht reports progress in the matter of the establishment of latitude stations in the southern hemisphere (cf. *Monthly Notices*, lxiii. pp. 294, 394). The Central Bureau have now arranged for the actual commencement of southern latitude work in 1906 January at two stations on the parallel $-31^\circ\ 55'$: one of these is at Bayswater, in West Australia, in longitude $-115^\circ\ 54'\cdot5$, and the other at Oncativo, in Argentina, in longitude $63^\circ\ 42'$. Dr. Curt Hessen and Dr. Luigi Carnera have respectively been appointed to the charge of the work.

The Next International Scheme. A Suggestion.
By W. Ernest Cooke.

The great photographic Durchmusterung is approaching completion. At a number of observatories this special work will soon be finished, and the officers in charge will be looking for the most useful direction towards which they may turn their energies. Now is the time, therefore, to consider the advisability of continuing the practice of international co-operation, and to discuss suggestions for the next concerted action.

I wish to put forward a plea for united effort in meridian work. Our present haphazard method leads to disappointing results, altogether disproportionate to the skill and labour expended. If the millions of observations that have been taken in the past had been properly co-ordinated we ought to be able to obtain good star positions in abundance in any portion of the sky. This is certainly not the case at present. It is a matter of every-day occurrence that an astronomer desires a number of reference points in some particular field, and as a general rule is obliged to use approximate positions first, and re-observe his reference stars with the transit circle at the next convenient opportunity. If he attempt to obtain the positions from existing catalogues he will probably find that most of his star positions have been determined *once* somewhere or other; but he will be very fortunate if he obtains sufficiently accurate information to bring the positions up to date. It is, moreover, disappointing to the transit observer to feel that he is putting an immense amount of work into a catalogue the greater part of which will never be used.

I believe both these difficulties will be overcome by the following plan:

Let three catalogues be prepared as soon as possible, and astronomers be requested to confine their meridian or other

exact work in future mainly to the stars in one or other of th catalogues.

A. Bright stars. This does not form part of the propo scheme, but, of course, the regular observation of the princi stars must be continued.

B. Fundamental stars for the general scheme. As matter of detail I suggest that these be selected of about sixth magnitude, and in every region of the sky.

C. Main catalogue, comprising, say, three stars to ev square degree, and, of course, including the whole of B. T would make a total of over 120,000 stars.

Leaving A to take care of itself, astronomers would be as to take up *either* B or C. In observing the B stars accur would be the main consideration, and no amount of time trouble should be begrudged for this end. They might also observed by totally different methods, such as that of almucantar. In fact, all the resources of exact astrono should be brought to bear upon the compilation of this ca logue. The positions thus obtained would be adopted as foundation of the C list. Observers taking up this m catalogue would work through one or two degrees of decli tion at a time, including at least six of the fundamental stars each evening's work, and obtaining from them the clock err and zenith, or equator point. They need not be troub greatly with anomalies in refraction, reflection, instrumen errors, &c., as their computations would be mainly differential

In working out the general scheme each observatory mi gradually advance zone by zone from the zenith to the p arranging for suitable overlaps; or might take charge of certain section of the sky and repeat every ten years; or th might be a combination of both methods. But the main po is that the position of each star would be determined with accuracy during each decade; and by the time we are ready repeat the photographic work now occupying our attention standard stars will be ready waiting for us, their positions det mined with great accuracy, and their proper motions kno with some amount of precision. By that time also the int national catalogue will be universally adopted, and all haphaz meridian work will have ceased.

The main idea of this scheme is the preparation of t catalogues, and the promise of some of the leading astronom to make one or the other the basis of their future working li A considerable proportion of the labour of compiling C been already done in selecting the standard stars for the pho graphic Durchmusterung. There would be some distinct adva tages in utilising these same stars; but, whatever method adopted, the list should be prepared, sanctioned by leadi astronomers, and printed. The preparation of B would requ great care, but would probably be undertaken by those w have already performed similar work, such as Professor Auwe

This is all that is really necessary, for when the lists are once sanctioned observers who have the opportunity can start work immediately, knowing that *not one single observation will thenceforward be wasted*, and that the sooner they commence the more valuable will their results eventually become.

Of course an international committee ought, if possible, to be appointed, to meet occasionally and see that there are no gaps; and if they have opportunities of obtaining funds for printing so much the better; but this, though desirable, is not essential. Let us have the scheme discussed, and, if considered advisable, have the catalogues prepared forthwith.

Perth Observatory, Western Australia:
1905 *July* 4.

On the Secular Accelerations of the Moon's Longitude and Node.
By P. H. Cowell.

In this paper I determine the secular accelerations of the Moon's longitude and node from the solar eclipses of the years −1062, −762, −647, −430, and +197.

The historical references are as follows:—

1. Inscription at Babylon:

"On the 26th day of the month Sivan, in the 7th year, the day was turned into night, and fire in the midst of heaven."

This inscription was communicated to me by Mr. L. W. King, of the Department of Egyptian and Assyrian Antiquities, British Museum, the translator, early in September. I may add that a few days previously I had shown to Professor Newcomb, in MS., the corrections that I had deduced from the other four eclipses mentioned in this paper. It turned out that this eclipse supported the corrections deduced from the other four.

2. Inscription at Nineveh:

"In the month Sivan the Sun underwent an eclipse."

3. Archilochus, 74:

Ζεὺς πατὴρ Ὀλυμπίων
ἐκ μεσημβρίης ἔθηκε νύκτ' ἀποκρύψας φάος
ἡλίου λάμποντος.

4. Thucydides, II. 28:

Τοῦ δ' αὐτοῦ θέρους νουμηνίᾳ κατὰ σελήνην, ὥσπερ καὶ μόνον δοκεῖ εἶναι γίγνεσθαι δυνατόν, ὁ ἥλιος ἐξέλιπε μετὰ μεσημβρίαν καὶ πάλιν ἀνεπληρώθη, γενόμενος μηνοειδὴς καὶ ἀστέρων τινῶν ἐκφανέντων.

5. Tertullian ad Scapulam, c. 3:

"Nam et sol ille in conventu Uticensi, extincto pæne lumine, adeo portentum fuit, ut non potuerit ex ordinario deliquio hoc pati, positus in suo hypsomate et domicilio. Habetis astrologos."

The method is as follows :—

Let T be an approximate time reckoned in Julian centu[ries] from 1800 January 0·0 G.M.T.

Let V, U, p be the Moon's tabular longitude and latit[ude] and parallax; let V+ΔV, U+ΔU be the Moon's true longit[ude] and latitude.

Let V′, p' be the Sun's tabular longitude and parallax.

Let v', u' be the parallax in longitude and latitude calcula[ted] for the Sun's place with the negative parallax $p'-p$.

Let T+t be the time of apparent conjunction in longitude.

For convenience t is measured in units of one-millionth p[art] of a Julian century, or about fifty-three minutes.

Thus by definition of t

$$V-V'-v'+t\frac{d}{dt}(V-V'-v')+\Delta V=0$$

If the place chosen for calculation is on the central line, t[hen] the apparent latitudes must be equal; or

$$U-u'+t\frac{d}{dt}(U-u')+\Delta U=0$$

Eliminate t; put

$$\frac{d}{dt}(U-u')=k\frac{d}{dt}(V-V'-v')$$

then

$$\Delta U-k\Delta V=k(V-V'-v')-(U-u')$$

This is the equation of condition for centrality. k is usu[ally] a small fraction, but its maximum value is $\frac{1}{3}$. It will [be] observed that ΔV has k as a factor. The central line r[uns] eastward; an alteration of V alters the time at which the M[oon] is interposed between the Earth and the Sun, and therefore [the] face of the Earth turned to the Sun is altered by diurnal rotat[ion]. This course alone shifts every point on the central line due [east] or west; and the two positions of the central line are not [very] widely separated, except that one line overlaps the other a[t its] west end and the other at its east.

If we assume that the parts of ΔV, ΔU that arise f[rom] corrections to the secular accelerations outweigh in import[ance] all other corrections required by the tables (this is obviously [the] case if the tabular secular accelerations are one second in er[ror]), we may put

$$\Delta U=\pm 0{\cdot}0895T^2 s_F \qquad \Delta V=T^2 s_L$$

where s_F, s_L are the corrections required by the secular acce[lera]tions of the argument of latitude and mean longitude.

The Hansen-Newcomb tables of the Moon now in use in the *Nautical Almanac* are based upon the following formulæ :

$$
\begin{aligned}
g &= 110^\circ\ 19'\ 32''{\cdot}50 + 171791\ 5807''{\cdot}98T + 45''{\cdot}675T^2 + 0''{\cdot}050073T^3 \\
\omega &= 192\ \ \ 7\ 21{\cdot}91 + \ \ 2161\ 1522{\cdot}07T - 44{\cdot}323T^2 - 0{\cdot}043759T^3 \\
-\Omega &= 326\ 43\ 28{\cdot}85 + \ \ \ 696\ 2939{\cdot}61T - \ 8{\cdot}189T^2 - 0{\cdot}007159T^3
\end{aligned}
$$

The Newcomb tables of the Sun now in use in the *Nautical Almanac* are based upon the formulæ

$$
\begin{aligned}
L' &= 279^\circ\ 54'\ 28''{\cdot}75 + 12960\ 2765''{\cdot}95T + 1''{\cdot}089T^2 \\
\pi' &= 279\ 29\ 47{\cdot}26 + \qquad 6185{\cdot}80T + 1{\cdot}590T^2 + 0''{\cdot}012T^3
\end{aligned}
$$

where I have transferred the epoch to 1800 Jan. 0·0 G.M.T.

The formulæ employed in the present calculations are

$$
\begin{aligned}
g &= 110^\circ\ 19'\ 38'' + 171791\ 5794''T + 44''{\cdot}4T^2 + 0''{\cdot}050T^3 \\
\omega &= 192\ \ \ 7\ 25 + \ \ 2161\ 1516T - 40{\cdot}0T^2 - 0{\cdot}044T^3 \\
-\Omega &= 326\ 43\ 39 + \ \ \ 696\ 2921T - \ 3{\cdot}7T^2 - 0{\cdot}007T \\
L' &= 279\ 54\ 29 + 12960\ 2766T + \ 1{\cdot}1T^2 \\
\pi' &= 279\ 29\ 47 + \qquad 6186T + \ 1{\cdot}6T^2 + 0{\cdot}012T^3
\end{aligned}
$$

The solar elements L', π', and the cube terms of the lunar elements have been modified only to the extent of omitting a few insignificant figures. The other alterations are

$$
\begin{aligned}
\Delta g &= +\ \ 5''{\cdot}50 - 13''{\cdot}98T - 1''{\cdot}275T^2 \\
\Delta\omega &= +\ \ 3{\cdot}09 - \ 6{\cdot}07T + 4{\cdot}323T^2 \\
-\Delta\Omega &= +10{\cdot}15 - 18{\cdot}61T + 4{\cdot}489T^2
\end{aligned}
$$

whence

$$
\begin{aligned}
\Delta L &= -1''{\cdot}56 - \ 1''{\cdot}44T - 1''{\cdot}441T^2 \\
\Delta\varpi &= -\ 7{\cdot}06 + 12{\cdot}54T - 0{\cdot}166T^2 \\
\Delta F &= +8{\cdot}59 - 20{\cdot}05T + 3{\cdot}048T^2
\end{aligned}
$$

The constants and centennial motions are approximately those deduced by myself from modern observations. The secular accelerations of L and F are approximately those deduced in the present investigation, which has been rewritten with the corrections introduced. The secular term of the perigee is hardly altered from Hansen. I decided not to introduce into it an empirical correction of $+3''$ with a possible error of $\pm 7''$, which I deduced in *Monthly Notices*, lxv. p. 275, from the observations 1750–1901.

The mean motions employed are probably correct to within $5''$. An error of $5''$ in any mean motion can be approximately balanced by an alteration $0''{\cdot}3$ in the secular term

No correction for the position of the perigee is introdu into the equations of condition. If all the eclipses conside occurred at perigee, an error in the perigee could be balanced an alteration of the mean longitude of one-ninth the amou With the actual eclipses employed, the residuals could diminished by a properly chosen correction to the perigee, such a correction would not be entitled to any weight.

The secular acceleration of the mean sidereal mot employed in my tabular places is $+7''\cdot0$.

The inequalities of the Moon are calculated from the foll ing formulæ:

$$
\begin{aligned}
V-L = {} & 22640'' \sin g \\
& + 4586 \sin(-g+2D) \\
& + 2370 \sin 2D \\
& + 769 \sin 2g \\
& + 669 \sin -g' \\
& + 412 \sin -2F \\
& + 212 \sin(-2g+2D) \\
& + 206 \sin(-g-g'+2D) \\
& + 192 \sin(g+2D) \\
& + 165 \sin(-g'+2D) \\
& + 148 \sin(g-g') \\
& + 125 \sin -D \\
& + 110 \sin(-g-g') \\
& + 55 \sin(-2F+2D) \\
& + 45 \sin(-g-2F) \\
& + 40 \sin(g-2F) \\
& + 38 \sin(-g+4D) \\
& + 36 \sin 3g \\
& + 31 \sin(-2g+4D) \\
& + 29 \sin(g-g'-2D) \\
& + 24 \sin(-g'-2D)
\end{aligned}
$$

$$
\begin{aligned}
U = {} & 18461'' \sin F \\
& + 1010 \sin(g+F) \\
& + 1000 \sin(g-F) \\
& + 624 \sin(-F+2D) \\
& + 199 \sin(-g+F+2 \\
& + 167 \sin(-g-F+2 \\
& + 117 \sin(F+2D) \\
& + 62 \sin(2g+F) \\
& + 33 \sin(g-F+2D) \\
& + 32 \sin(2g-F) \\
& + 30 \sin(-g'-F+2 \\
& + 16 \sin(-2g-F+2 \\
& + 15 \sin(g+F+2D) \\
& + 12 \sin(-g'+F-2
\end{aligned}
$$

$$p-p' = 3414''+187''\cos g+34''\cos(-g+2D)$$
$$+28''\cos 2D+10''\cos 2g$$

$$\frac{d}{dt}(V-V') = 1632''+227''\cos g \qquad +13''\cos 2g-5\ \mathrm{co}$$

$$\pm\frac{dU}{dt} = 163''+ 20''\cos g \qquad + 2''\cos 2g$$

The last two expressions have been reduced by putting D =

$2F = 0$ in the accurate expressions. For the Sun the formula used is

$$V' - L' = e_1' \sin g' + e_2' \sin 2g'$$

where

$$e_1' = 6927''{\cdot}2 - 17''{\cdot}14T - 0''{\cdot}052T^2$$
$$e_2' = \quad 72{\cdot}7 - \quad 0{\cdot}36T$$

The corrections for parallax are calculated by the formulæ

$p - p') \sin \lambda \sin \epsilon \cos V'$	$\dfrac{dv'}{dt} =$
$p - p') \cos \lambda \cos^2 \dfrac{\epsilon}{2} \sin (h - V')$	$0{\cdot}2295 \times (p - p') \cos \lambda \cos^2 \dfrac{\epsilon}{2} \cos (h - V')$
$p - p') \cos \lambda \sin^2 \dfrac{\epsilon}{2} \sin (h + V')$	$-0{\cdot}2307 \times (p - p') \cos \lambda \sin^2 \dfrac{\epsilon}{2} \cos (h + V')$

$p - p') \sin \lambda \cos \epsilon$	$\dfrac{du'}{dt} =$
$p - p') \cos \lambda \sin \epsilon \sin h$	$-0{\cdot}2301 \times (p - p') \cos \lambda \sin \epsilon \cos h$

where ϵ is the obliquity of the ecliptic

$$\epsilon = 23^\circ\ 27'\ 55''{\cdot}1 - 46''{\cdot}83T$$
$$\sin \epsilon = 0{\cdot}4023\ 5 - 0{\cdot}0002\ 1(T+20)$$
$$\cos \epsilon = 0{\cdot}9154\ 9 + 0{\cdot}0000\ 9(T+20)$$

and λ is the latitude of the place of calculation and h the local sidereal time.

Owing to their rapid curvature the parallactic corrections for $T+t$ can only be calculated by the formula given, if the correction t is small.

The numerical work is given below. The calculations are extended to the eclipse of -1069 June 20, in order to show that the eclipse of this date was not total at Babylon. I should add that Mr. King would have much preferred a date in June being assigned to his eclipse instead of a date in July, owing to the reference to the month Sivan.

Ref. No.	T.	Place.	Authority.	Lat. N.	Long. N.
				° ′	° ′
0	−28·6850167	Babylon	...	+32 26	+44 13
1	−28·6138889	"	Inscription	+32 26	+44 13
2	−25·6151436	Nineveh	"	+36 24	+43 0
3	−24·4670532	Thasos	Archilochus	+40 40	+24 40
4	−22·2937936	Athens	Thucydides	+37 56	+23 38
5	−16·0254612	Utica	Tertullian	+37 10	+10 0

Ref. No.	Local Mean Time Corresponding to T.				T.	T².	0·0895 T².	*e*.
		d	h	m				° ′
0	−1069 June	19	28	18·5	822·83	−23603	74	303 41
1	−1062 July	30	19	56·3	818·75	−23428	73	45 44
2	− 762 June	14	23	59·2	656·14	−16807	59	41 35
3	− 647 April	5	22	48·5	598·64	−14647	54	348 18
4	− 430 Aug.	3	6	6·3	497·01	−11080	45	264 2
5	+ 197 June	3	1	22·7	256·82	− 4116	23	262 4

Ref. No.	ω.	−Ω.	L′.	ϖ′.	L.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′
0	61 24 33	284 57 15	77 31 7	230 29 35	80 8
1	128 26 48	62 31 46	118 10 23	230 36 50	111 39
2	132 14 13	102 41 28	75 15 29	235 43 0	71 8
3	185 3 51	163 19 9	7 22 37	237 40 16	10 3
4	272 39 36	46 48 55	126 21 40	241 22 20	129 53
5	105 17 21	290 54 38	71 4 14	252 3 35	76 27

Ref. No.	V−L.	V′−L′.	V−V′.	U.	$\frac{d}{dt}$(V−V′).	$\frac{dU}{dt}$	*p*−
0	−14907″	−3285″	−2159″	+ 231″	+1757″	+173″	35
1	+13676	−6758	−2996	+ 718	+1792	−177	35
2	+12442	−2399	− 8	+ 875	+1809	−178	36
3	− 4176	+5548	− 98	+2375	+1869	−185	36
4	−17107	−6538	+2130	+2577	+1597	−159	34
5	−17951	+ 121	+1310	+ 776	+1593	+158	33

Ref. No.	*h* = Local Sid. Time.	*v*′.	*u*′.
	° ′		
0	37 9	+179−1827−117 = −1765″	+1745− 733 = +101
1	57 14	−345−2488− 15 = −2848	+1761−1029 = + 7
2	75 3	+229+ 23− 62 = + 190	+1957−1131 = + 8
3	349 31	+952− 885+ 3 = + 70	+2187+ 204 = +23
4	217 57	−478+2567+ 34 = +2123	+1916+ 665 = +25
5	91 45	+267+ 914− 34 = +1147	+1877−1086 = + 7

Ref. No.	$\frac{dv'}{dt}$.	$\frac{du'}{dt}$.	$\frac{d}{dt}$(V−V′−*v*′) = denom. of *k*.	$\frac{d}{dt}$(U−*u*′) = num. of *k*.	*k*
0	+510+12 = +522″	−222″	+1235″	+395″	+·3
1	+342+30 = +372	−153	+1420	− 24	−·0
2	+638+24 = +662	− 69	+1147	−109	−·0
3	+576−27 = +549	−254	+1320	+ 69	+·0
4	− 35−25 = − 60	+196	+1537	−355	−·2
5	+557+25 = +582	+ 8	+1011	+150	+·1

Ref. No.	$-kT'$.	$V-V'-v'$.	t.	$k(V-V'-v') -(U-u')$.
0	−263	−394	+0·3	+655″
1	+ 13	−148	+0·1	+ 17
2	+ 62	−198	+0·2	− 30
3	− 31	−168	+0·1	+ 8
4	+115	+ 7	0·0	+ 2
5	− 38	+163	−0·2	+ 39

The large value in the first line of the last column shows that about one-third of the Sun was visible at Babylon at the maximum phase of the eclipse of −1069 June 20.

The equations of condition resulting from the other five eclipses are :

$$-73\,s_F + 13\,s_L = +17''$$
$$-59\,s_F + 62\,s_L = -30$$
$$-54\,s_F - 31\,s_L = +8$$
$$-45\,s_F + 115\,s_L = +2$$
$$+23\,s_F - 38\,s_L = +39$$

In some cases the right-hand sides are less than the difference of semi-diameters. A least-squares solution gives $s_L = -0''\cdot18$, $s_F = -0''\cdot05$; but these quantities are less than the probable errors.

The eclipse of Agathocles −309 Aug. 15 is central about fifty miles north of Syracuse. The figures are not reproduced here.

The equation of condition for the eclipse of −1062 shows that, with Hansen's position of the node, totality, even in the neighbourhood of Babylon, is impossible without a large increase of the secular acceleration.

On the Value of Ancient Solar Eclipses. By P. H. Cowell.

In *Ast. Nach.*, No. 3682, Professor Newcomb argues against the corrections to the three lunar elements, viz. the mean longitude and the longitude of perigee and node, based by Oppolzer and Ginzel on ancient solar eclipses. These corrections, as Professor Newcomb points out, are incompatible with modern observations and with theory, and I, like Professor Newcomb, believe them to be erroneous.

In the opening paragraphs of the paper referred to, Professor Newcomb lays down that " no attempt should be made to determine the motion either of the perigee or node from ancient eclipses " on the ground that their centennial motions have been settled by the accordance of modern observation with theory to within limits of error that would have no " appreciable effect on the paths of ancient eclipses." Professor Newcomb, however, ignores the possibility of errors in the secular variations. Now

cular variations cannot be determined to within 5
observations, and the theory is certainly not a
n. No theoretical values have to my knowledge
ed since Hansen's, who, in the case of the mean lo
ve the erroneous value of 12″.

any error in the assumed value of g, the mean anom
ces into the Moon's tabular longitude an error $\frac{1}{9}$
e same amount. Probably, therefore, the secular
osition of the perigee cannot be determined from an
with an accuracy much superior to that resulting
observations.

sen's secular term in the longitude of the node, how
e to be erroneous by over 4″, corresponding to an err
ne degree in the earliest eclipses. Modern observa
criticise this correction, and the objection to it is wh
cal.

r on in the paper referred to, Professor Newcomb r
stion, "To what extent, if at all, are we justifie
ning the secular acceleration of the Moon from
l solar eclipses recorded by ancient historians?" W
mine Professor Newcomb's distrust of ancient
we find it is mainly, if not entirely, due to the fact
pse of Xerxes, in the spring of the year of Sala
e identified at all, and that in the eclipse of Thales (—
values of the secular acceleration make the central

tions satisfy the equations of condition for five eclipses, and that one of these corrections is further supported by Mr. Nevill's amendment (*Monthly Notices*, vol. xxxix.) to Professor Newcomb's discussion of ancient lunar eclipses. If the eclipses were total, the numerical values of my corrections are correct; if the eclipses were partial, then the amazing accident must have occurred that all five are such that they can be rendered tabularly total by the same alterations of the tables.

The Annular Eclipse, 1905 *March* 6, *observed in South Australia.* Communicated by Sir Charles Todd, K.C.M.G., F.R.S.

The conditions for observing the recent partial eclipse of the Sun in South Australia were extremely favourable. As shown in the *Nautical Almanac*, the central line entered the Australian continent at the head of the Great Bight, and emerged on the East Coast about lat. 22° 50′, passing therefore through our sparsely settled interior. In Adelaide the magnitude of the eclipse was 0·827; at Cradock (lat. 32° 5′) the observer says the annulus was almost discernible at mid-phase. I was unfortunately away in Melbourne, but Mr. Griffiths made very careful observations and furnishes the following notes.

"The eclipse was observed under very good atmospheric conditions. The first contact was noted at $1^h\ 51^m\ 52^s{\cdot}9$ standard time, or $1^h\ 36^m\ 13^s{\cdot}2$ Adelaide mean time. This is probably within a second or two of the real time, as I was looking at the exact spot: the limb was beautifully defined, and the merest indentation was observed. There were two large groups of spots on the Sun visible to the naked eye, one on the western side and the other in the eastern hemisphere. The Moon reached the western group at $2^h\ 14^m\ 37^s{\cdot}9$, or $1^h\ 58^m\ 58^s{\cdot}2$ A.M.T., and finally covered it at $2^h\ 23^m\ 25^s{\cdot}8$, or $2^h\ 7^m\ 46^s{\cdot}1$ A.M.T.; the second or larger group was reached at $2^h\ 58^m\ 5^s{\cdot}4$ ($2^h\ 42^m\ 25^s{\cdot}7$ A.M.T.), and finally covered at $3^h\ 9^m\ 43^s{\cdot}4$ ($2^h\ 54^m\ 3^s{\cdot}7$ A.M.T.) The definition was at times perfect, and the most careful scrutiny of the spots as they passed behind the Moon failed to reveal any distortion or change in their appearance: the colour of their umbræ seemed to be decidedly lighter in tone than the black Moon. The final contact was noted at $4^h\ 54^m\ 26^s{\cdot}1$, or $4^h\ 38^m\ 46^s{\cdot}4$ A.M.T., and was very exact, the limb being steady.'

Taking the time of final contact, Captain Lee, the Superintendent of Prince Alfred Sailors' Home, Port Adelaide, made the longitude of the Observatory $9^h\ 14^m\ 15^s{\cdot}3$, the adopted longitude from a number of observations and comparisons with Melbourne and Sydney Observatories being $9^h\ 14^m\ 20^s{\cdot}3$, an excellent result from a single observation.

The following temperature observations were made at the Observatory.

Standard Time.		Shade. D.B.	Shade. W.B.	Relative Humidity.	Solar. Lampblack Bulb in Vacuo.	Solar. Lampblack Bulb not in Vacuo.
h m s	h m			%		
(1 44 20·3 A.M.T.)	2 0	69·5	58·0	48	126·7	103·8
	10	71·1	58·6	46	126·8	105·5
	20	69·7	58·2	48	124·8	104·3
	30	69·5	58·6	50	118·8	97·5
	40	68·2	57·3	49	109·0	91·0
	50	68·7	58·0	51	102·0	89·1
	3 0	67·3	57·2	52	95·6	85·2
	10	66·2	56·7	54	88·0	78·5
	20	66·0	57·1	56	81·1	75·3
	30	65·2	57·0	58	76·8	73·0
	40	64·5	56·8	60	76·5	72·0
	50	64·9	57·2	60	80·4	75·7
	4 0	65·3	57·0	58	86·5	79·0
	10	66·0	57·1	56	92·5	83·0
	20	66·8	57·5	55	98·2	84·5
	30	67·0	57·8	55	102·5	90·0
	40	67·0	58·0	56	105·3	92·0
	50	67·0	58·0	56	106·2	92·3
	5 0	67·1	57·8	55	105·4	...

Similar observations made by both private and official observers throughout the State give very similar differences to the above.

My friend Mr. A. W. Dobbie, who is a member of our local Astronomical Society and of the New South Wales branch of the B.A.A., and is an enthusiastic amateur astronomer, took a series of very interesting photographs, using an 18-inch silvered glass reflector, stopped down to 4½ inches, copies of which (nine in all) I enclose. The first was taken at 1^h 58^m 5^s standard time, or 1^h 42^m 25^s A.M.T., and the last at 4^h 54^m 3^s (4^h 38^m 23^s A.M.T.) or 23 seconds before final contact. The central phase which occurred at 3^h 30^m standard time, is nearly shown by No. 5 taken at 3^h 27^m 37^s. I might add that these are Mr. Dobbie's first attempts to photograph the Sun, and, further, that he ground the mirror, silvered it, and mounted it himself.

The decrease in the actinic power of the light during the eclipse was noted both here and at other places by exposing sensitised paper for definite periods as the eclipse progressed and a measure of the decrease was obtained by the Rev. N. H. Louwyck, of Georgetown, by means of a Wynn Infallible Print Meter—this showed that with 16 as the value before the eclipse it decreased to between 5 and 6 (or ⅓) at the middle phase.

The Observatory, Adelaide:
1905 *June* 8.

Observations of Vesta made at the Natal Observatory, Durban. Communicated by E. Nevill.

The following observations were made by Mr. Rendell by means of a cross-bar micrometer with the equatorial refractor, aperture 8 inches, focal length 10 feet. Magnifying power 50.

Date. 1905.	Greenwich Mean Time.	Apparent Difference. Vesta minus Star. R.A.	N.P.D.	Vesta's Approx. Hour-Angle.	No of Com-parisons.	Com-parison Star.
	h m s	m s	″	h m		
May 23	3 54 27	+1 30·64	−8 11·3	2 3 E.	7	*a*
„	5 38 53	+1 32·12	−7 57·8	0 18 E.	4	*a*
„	6 32 2	+1 32·64	−7 29·3	0 35 W.	4	*a*
24	6 47 21	+1 52·26	−0 41·3	0 54 W.	7	*a*
25	3 54 55	+2 11·01	+5 20·9	1 55 E.	6	*a*
July 4	6 57 47	+3 18·25	−3 53·2	3 13 W.	2	*b*
13	6 51 55	+4 39·32	+1 33·7	3 32 W.	5	*c*

Comparison Stars.

		R.A.	N.P.D.
		h m s	° ′ ″
a.	Lalande 22743 (Paris 14796)	12 0 47·61	79 38 27·2 (1875·0)
b.	„ 23608 („ 15505)	12 31 42·27	86 1 45·3 „
c.	„ 23851 („ 15726)	12 41 17·62	87 37 51·3 „

Notes.

The observations have not been corrected for refraction or parallax.

May 23. The following observations were obtained with the 3-inch transit instrument:—

$$\left.\begin{array}{l}\text{R.A. of Star } a = 12^h\ 2^m\ 21^s{\cdot}02 \\ \text{R.A. of Vesta} = 12\ 3\ 53{\cdot}07\end{array}\right\}\text{Diff.} = 1^m\ 32^s{\cdot}05\ (\text{G.M.T.} = 5^h\ 57^m\ 10^s)$$

July 4. Cloudy, observation doubtful.

Natal Observatory, Durban:
1905 *August* 31.

he Magnitude of η Argûs, 1905. By R. T. A. Innes

two comparison stars used are the same as on f
ns (*Monthly Notices*, lix. p. 570), viz. C. G. A. C
ue, No. 121, mag. 8·0, colour on Chandler's scale 8
1332, mag. 7·6, colour 4. The telescope used, a 4
r, belongs to Mr. R. N. Kotze.

1905	May	20	mag. =	7·8		
	"	25	"	7·6		
	June	3	"	7·7	colour	7
	"	24	"	7·55	"	8
	"	25	"	7·7		
1905·5			"	7·67	"	7½

change, if any, since 1896 is quite insignificant.

nnesburg : 1905 *June* 27.

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meris for Physical Observations of the Moon for 19

reenwich Midnight.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Sel. Long. of the Earth.	Lat.	Physical Libration. Long.	Lat.	C.
1906.	°	°	°	°	°	°	°
an. 17	183·38	+0·63	−1·83	−6·22	−·013	+·026	21·16
18	195·54	+0·61	−0·76	−6·67	−·012		17·50
19	207·71	+0·58	+0·40	−6·70	−·010		12·71
20	219·89	+0·56	+1·58	−6·32	−·010		7·06
21	232·07	+0·53	+2·71	−5·55	−·009		0·89
22	244·26	+0·51	+3·70	−4·44	−·009		354·65
23	256·45	+0·49	+4·49	−3·07	−·009		348·79
24	268·64	+0·46	+5·00	−1·55	−·009		343·76
25	280·83	+0·44	+5·20	+0·03	−·010		339·81
26	293·02	+0·41	+5·07	+1·57	−·010		337·10
27	305·21	+0·39	+4·63	+3·00	−·011		335·61
28	317·40	+0·36	+3·89	+4·25	−·013		335·30
29	329·58	+0·34	+2·92	+5·28	−·015		336·07
30	341·76	+0·31	+1·78	+6·07	−·017		337·83
31	353·93	+0·29	+0·54	+6·58	−·018		340·47
'eb. 1	6·09	+0·26	−0·74	+6·81	−·020		343·92
2	18·25	+0·23	−1·97	+6·76	−·023		348·10
3	30·40	+0·20	−3·09	+6·41	−·025		352·89
4	42·55	+0·17	−4·02	+5·76	−·026		358·14
5	54·69	+0·14	−4·73	+4·84	−·027	+·026	3·64
6	66·83	+0·11	−5·16	+3·65	−·028	+·027	9·12
7	78·96	+0·08	−5·29	+2·26	−·029		14·22
8	91·09	+0·05	−5·12	+0·70	−·030		18·60
9	103·23	+0·01	−4·67	−0·92	−·030		21·95
10	115·36	−0·02	−3·96	−2·52	−·030		24·03
11	127·50	−0·05	−3·06	−3·99	−·030		24·72
12	139·64	−0·08	−2·00	−5·22	−·029		23·95
13	151·79	−0·11	−0·87	−6·13	−·027		21·81
14	163·94	−0·14	+0·28	−6·65	−·026		18·38
15	176·10	−0·17	+1·37	−6·77	−·025		13·84
16	188·27	−0·20	+2·37	−6·47	−·025		8·43
17	200·45	−0·22	+3·23	−5·79	−·023		2·48
18	212·63	−0·25	+3·92	−4·77	−·023		356·37
19	224·82	−0·27	+4·42	−3·50	−·023		350·52
20	237·01	−0·30	+4·71	−2·04	−·023		345·31
21	249·21	−0·32	+4·78	−0·49	−·023		341·05
22	261·41	−0·35	+4·62	+1·06	−·024		337·93
23	273·62	−0·37	+4·24	+2·53	−·025	+·027	336·02

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1906.		°	°	°	°	°	°	
Feb.	24	285·82	−0·39	+3·63	+3·84	−·025	+·027	3
	25	298·02	−0·42	+2·82	+4·96	−·026		3
	26	310·21	−0·44	+1·83	+5·83	−·028		3
	27	322·41	−0·47	+0·69	+6·43	−·030		3
	28	334·60	−0·49	−0·55	+6·75	−·032		3
Mar.	1	346·79	−0·52	−1·82	+6·78	−·033		3
	2	358·97	−0·54	−3·07	+6·52	−·035		3
	3	11·14	−0·57	−4·23	+5·97	−·037		3
	4	23·31	−0·60	−5·21	+5·15	−·038		
	5	35·47	−0·63	−5·94	+4·08	−·039		
	6	47·63	−0·66	−6·36	+2·78	−·040		1
	7	59·78	−0·68	−6·41	+1·29	−·040		1
	8	71·93	−0·71	−6·06	−0·30	−·040		2
	9	84·08	−0·74	−5·31	−1·92	−·040		2
	10	96·22	−0·77	−4·20	−3·46	−·039		24
	11	108·37	−0·80	−2·81	−4·80	−·038		24
	12	120·51	−0·82	−1·24	−5·83	−·037		22
	13	132·66	−0·85	+0·37	−6·48	−·036		19
	14	144·82	−0·87	+1·90	−6·69	−·035		15
	15	156·99	−0·90	+3·24	−6·48	−·033		9
	16	169·16	−0·92	+4·31	−5·86	−·032		3
	17	181·34	−0·94	+5·07	−4·91	−·031		357
	18	193·52	−0·96	+5·53	−3·69	−·030		351
	19	205·72	−0·98	+5·69	−2·29	−·030		346
	20	217·92	−0·99	+5·60	−0·80	−·030		342
	21	230·13	−1·01	+5·27	+0·71	−·030		338
	22	242·34	−1·03	+4·76	+2·16	−·030		336
	23	254·55	−1·04	+4·07	+3·48	−·031		335
	24	266·77	−1·06	+3·24	+4·62	−·032		335
	25	278·99	−1·08	+2·27	+5·54	−·034		336
	26	291·20	−1·10	+1·18	+6·20	−·035		338
	27	303·42	−1·11	−0·01	+6·57	−·036		341
	28	315·63	−1·13	−1·27	+6·64	−·038		345
	29	327·84	−1·15	−2·56	+6·47	−·039		349
	30	340·04	−1·17	−3·84	+6·00	−·040		354
	31	352·24	−1·19	−5·03	+5·26	−·041		359
Apr.	1	4·43	−1·21	−6·08	+4·28	−·042		5
	2	16·62	−1·23	−6·89	+3·09	−·043	+·027	10

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1906.	°	°	°	°	°	°	°
pr. 3	28·80	−1·24	−7·39	+1·71	−·043	+·027	715·19
4	40·98	−1·26	−7·49	+0·20	−·043		19·29
5	53·15	−1·28	−7·14	−1·36	−·043		22·38
6	65·31	−1·30	−6·30	−2·89	−·042		24·22
7	77·47	−1·32	−5·00	−4·29	−·041		24·62
8	89·63	−1·33	−3·31	−5·42	−·040		23·50
9	101·79	−1·35	−1·37	−6·20	−·038		20·86
10	113·95	−1·36	+0·66	−6·54	−·037		16·81
11	126·12	−1·37	+2·59	−6·43	−·035		11·61
12	138·29	−1·39	+4·25	−5·89	−·033		5·64
13	150·47	−1·40	+5·54	−4·97	−·032		359·33
14	162·65	−1·41	+6·41	−3·77	−·030		353·19
15	174·85	−1·41	+6·84	−2·39	−·029		347·62
16	187·04	−1·42	+6·89	−0·92	−·028		342·94
17	199·25	−1·43	+6·60	+0·52	−·029		339·34
18	211·47	−1·43	+6·04	+1·95	−·029		336·89
19	223·68	−1·44	+5·28	+3·25	−·029		335·59
20	235·91	−1·45	+4·36	+4·39	−·029		335·41
21	248·13	−1·45	+3·32	+5·31	−·030		336·26
22	260·37	−1·46	+2·19	+5·98	−·031		338·09
23	272·60	−1·46	+1·00	+6·38	−·032		340·82
24	284·83	−1·47	−0·25	+6·50	−·034		344·33
25	297·07	−1·48	−1·54	+6·34	−·034		348·53
26	309·29	−1·48	−2·83	+5·90	−·035		353·28
27	321·52	−1·49	−4·10	+5·20	−·037		358·40
28	333·75	−1·50	−5·30	+4·27	−·038		3·68
29	345·96	−1·50	−6·37	+3·13	−·038		8·89
30	358·17	−1·51	−7·23	+1·83	−·038		13·75
ay 1	10·38	−1·51	−7·80	+0·45	−·038		18·00
2	22·57	−1·52	−8·00	−1·04	−·038		21·37
3	34·77	−1·52	−7·74	−2·52	−·037		23·64
4	46·95	−1·53	−6·99	−3·90	−·036		24·62
5	59·14	−1·53	−5·73	−5·08	−·035		24·16
6	71·31	−1·54	−4·01	−5·96	−·033		22·21
7	83·49	−1·54	−1·95	−6·43	−·031		18·76
8	95·66	−1·54	+0·25	−6·45	−·029		13·97
9	107·83	−1·53	+2·41	−6·00	−·027		8·14
10	120·01	−1·53	+4·31	−5·14	−·025	+·027	1·72

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1906	°	°	°	°	°	°	
May 11	132·20	−1·53	+5·83	−3·96	−·023	+·027	355
12	144·39	−1·52	+6·87	−2·55	−·022		349
13	156·58	−1·52	+7·42	−1·04	−·021		344
14	168·78	−1·51	+7·52	+0·48	−·020		340
15	181·00	−1·50	+7·22	+1·94	−·019		337
16	193·21	−1·50	+6·60	+3·26	−·018		335
17	205·44	−1·49	+5·72	+4·41	−·020		335
18	217·67	−1·48	+4·69	+5·33	−·021		335
19	229·90	−1·48	+3·53	+6·01	−·022		337
20	242·14	−1·47	+2·30	+6·43	−·023		340
21	254·39	−1·46	+1·03	+6·56	−·024		343
22	266·63	−1·46	−0·25	+6·41	−·024		347
23	278·88	−1·45	−1·53	+5·98	−·025		352
24	291·12	−1·45	−2·78	+5·29	−·025		357
25	303·36	−1·44	−3·99	+4·37	−·026		2
26	315·60	−1·43	−5·11	+3·24	−·026		7
27	327·84	−1·42	−6·11	+1·95	−·027		12
28	340·07	−1·42	−6·91	+0·55	−·027		16
29	352·30	−1·41	−7·47	−0·91	−·026		20
30	4·52	−1·40	−7·69	−2·36	−·025		23
31	16·73	−1·39	−7·51	−3·72	−·023		24
June 1	28·93	−1·39	−6·88	−4·91	−·022		24
2	41·13	−1·37	−5·78	−5·84	−·020		23
3	53·33	−1·36	−4·23	−6·41	−·018		20
4	65·52	−1·35	−2·34	−6·56	−·017		16
5	77·70	−1·34	−0·25	−6·25	−·015		10
6	89·89	−1·32	+1·85	−5·49	−·012		4
7	102·07	−1·30	+3·77	−4·35	−·010		357
8	114·26	−1·29	+5·36	−2·95	−·008		351
9	126·45	−1·27	+6·52	−1·38	−·007		345
10	138·65	−1·25	+7·20	+0·22	−·005		341
11	150·85	−1·23	+7·40	+1·76	−·005		338
12	163·06	−1·22	+7·19	+3·16	−·004		336
13	175·28	−1·20	+6·62	+4·37	−·003		335
14	187·50	−1·18	+5·77	+5·35	−·004		335
15	199·73	−1·16	+4·72	+6·08	−·006		337
16	211·97	−1·14	+3·53	+6·51	−·007		339
17	224·21	−1·12	+2·26	+6·67	−·007	+·027	342

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1906.	°	°	°	°	°	°	°
June 18	236·45	−1·11	+0·97	+6·55	−·008	+·027	346·41
19	248·70	−1·09	−0·31	+6·14	−·009		350·90
20	260·95	−1·07	−1·54	+5·47	−·009		355·87
21	273·21	−1·06	−2·71	+4·55	−·010		1·13
22	285·46	−1·04	−3·78	+3·42	−·011		6·44
23	297·71	−1·02	−4·74	+2·12	−·010		11·50
24	309·96	−1·01	−5·54	+0·70	−·010		16·04
25	322·20	−0·99	−6·16	−0·78	−·010		19·80
26	334·44	−0·97	−6·54	−2·24	−·009		22·58
27	346·67	−0·95	−6·65	−3·62	−·008		24·21
28	358·90	−0·93	−6·43	−4·83	−·007		24·59
29	11·12	−0·92	−5·84	−5·80	−·005		23·66
30	23·33	−0·90	−4·89	−6·44	−·003		21·40
July 1	35·54	−0·87	−3·59	−6·69	·000		17·83
2	47·74	−0·85	−2·02	−6·52	+·002		13·04
3	59·93	−0·83	−0·26	−5·90	+·003		7·25
4	72·13	−0·80	+1·52	−4·87	+·005		0·84
5	84·31	−0·78	+3·20	−3·53	+·008		354·31
6	96·50	−0·75	+4·64	−1·96	+·010		348·24
7	108·69	−0·72	+5·73	−0·30	+·011		343·11
8	120·89	−0·69	+6·42	+1·34	+·012		339·25
9	133·09	−0·66	+6·69	+2·85	+·013		336·72
10	145·29	−0·64	+6·56	+4·17	+·014		335·53
11	157·50	−0·61	+6·07	+5·24	+·014		335·55
12	169·71	−0·58	+5·29	+6·05	+·014		336·66
13	181·94	−0·56	+4·27	+6·56	+·013	+·027	338·72
14	194·17	−0·54	+3·10	+6·79	+·012	+·026	341·62
15	206·40	−0·51	+1·84	+6·72	+·012		345·29
16	218·64	−0·49	+0·56	+6·36	+·011		349·61
17	230·88	−0·46	−0·69	+5·73	+·010		354·45
18	243·13	−0·44	−1·86	+4·85	+·010		359·65
19	255·38	−0·42	−2·91	+3·74	+·009		4·99
20	267·63	−0·39	−3·81	+2·44	+·009		10·19
21	279·89	−0·37	−4·53	+1·00	+·009		14·94
22	292·13	−0·35	−5·04	−0·50	+·009		18·96
23	304·38	−0·33	−5·34	−2·01	+·010		22·02
24	316·63	−0·30	−5·40	−3·43	+·011		23·92
25	328·87	−0·28	−5·22	−4·69	+·012	+·026	24·59

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		°	°	°	°	°	°	
July	26	341·10	−0·26	−4·78	−5·71	+·013	+·026	23
	27	353·33	−0·23	−4·10	−6·42	+·015		22
	28	5·55	−0·21	−3·19	−6·75	+·016		18
	29	17·76	−0·18	−2·07	−6·68	+·018		14
	30	29·97	−0·15	−0·81	−6·19	+·020		9
	31	42·17	−0·12	+0·53	−5·30	+·022		3
Aug.	1	54·36	−0·09	+1·87	−4·06	+·024		356
	2	66·55	−0·06	+3·12	−2·58	+·025	+·026	359
	3	78·74	−0·03	+4·19	−0·94	+·027	+·025	345
	4	90·92	0·00	+5·02	+0·73	+·028		340
	5	103·11	+0·03	+5·55	+2·32	+·029		337
	6	115·30	+0·06	+5·74	+3·75	+·030		335
	7	127·49	+0·09	+5·60	+4·94	+·030		335
	8	139·69	+0·12	+5·15	+5·85	+·030		336
	9	151·89	+0·15	+4·40	+6·47	+·029		337
	10	164·10	+0·18	+3·43	+6·79	+·028		340
	11	176·31	+0·20	+2·28	+6·80	+·028		344
	12	188·53	+0·23	+1·03	+6·52	+·027		348
	13	200·76	+0·26	−0·24	+5·96	+·027		352
	14	212·99	+0·28	−1·48	+5·15	+·027		357
	15	225·22	+0·30	−2·60	+4·10	+·025		3
	16	237·46	+0·33	−3·56	+2·84	+·025		8
	17	249·70	+0·35	−4·29	+1·44	+·025		13
	18	261·95	+0·37	−4·77	−0·06	+·025		17
	19	274·19	+0·39	−4·96	−1·59	+·025		21
	20	286·43	+0·42	−4·86	−3·07	+·025		23
	21	298·68	+0·44	−4·49	−4·40	+·026		24
	22	310·91	+0·46	−3·88	−5·49	+·027		24
	23	323·15	+0·49	−3·06	−6·28	+·028		22
	24	335·38	+0·51	−2·11	−6·69	+·030		19
	25	347·60	+0·54	−1·07	−6·70	+·031		15
	26	359·81	+0·56	0·00	−6·30	+·033		10
	27	12·01	+0·59	+1·07	−5·51	+·035		4
	28	24·21	+0·61	+2·07	−4·38	+·037		358
	29	36·40	+0·64	+2·97	−2·99	+·038		352
	30	48·59	+0·67	+3·75	−1·44	+·040		346
	31	60·77	+0·70	+4·37	+0·19	+·040		342
Sept.	1	72·95	+0·73	+4·80	+1·78	+·041	+·025	338

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	°	°	°	°	°	°	°
Sept. 2	85·13	+0·75	+5·02	+3·25	+·042	+·025	336·37
3	97·30	+0·78	+5·00	+4·51	+·042		335·49
4	109·48	+0·81	+4·73	+5·52	+·042		335·81
5	121·66	+0·83	+4·20	+6·23	+·042		337·23
6	133·85	+0·86	+3·43	+6·64	+·041		339·62
7	146·03	+0·88	+2·44	+6·74	+·040		342·85
8	158·22	+0·90	+1·29	+6·54	+·039		346·78
9	170·42	+0·92	+0·02	+6·06	+·038		351·30
10	182·63	+0·94	−1·28	+5·33	+·037		356·26
11	194·83	+0·96	−2·54	+4·36	+·035		1·47
12	207·05	+0·98	−3·67	+3·19	+·035		6·73
13	219·27	+1·00	−4·60	+1·86	+·034		11·77
14	231·49	+1·02	−5·24	+0·41	+·033		16·31
15	243·72	+1·03	−5·55	−1·10	+·033		20·07
16	255·95	+1·05	−5·48	−2·59	+·033		22·78
17	268·18	+1·06	−5·02	−3·97	+·034		24·29
18	280·41	+1·08	−4·21	−5·14	+·035		24·42
19	292·64	+1·10	−3·12	−6·01	+·035		23·16
20	304·87	+1·11	−1·82	−6·52	+·036		20·54
21	317·09	+1·13	−0·46	−6·61	+·038		16·66
22	329·31	+1·15	+0·88	−6·27	+·039		11·72
23	341·51	+1·17	+2·10	−5·54	+·040		6·00
24	353·72	+1·19	+3·14	−4·47	+·042	+·025	359·86
25	5·91	+1·21	+3·97	−3·15	+·043	+·024	353·72
26	18·10	+1·23	+4·58	−1·66	+·045		348·04
27	30·27	+1·25	+4·98	−0·10	+·047		343·19
28	42·45	+1·27	+5·19	+1·45	+·047		339·44
29	54·62	+1·28	+5·22	+2·90	+·047		336·92
30	66·78	+1·30	+5·08	+4·17	+·047		335·65
Oct. 1	78·95	+1·32	+4·76	+5·21	+·047		335·61
2	91·11	+1·33	+4·25	+5·98	+·046		336·67
3	103·27	+1·35	+3·56	+6·42	+·045		338·76
4	115·43	+1·36	+2·68	+6·60	+·045		341·73
5	127·60	+1·38	+1·62	+6·46	+·043		345·46
6	139·77	+1·39	+0·41	+6·05	+·042		349·81
7	151·94	+1·40	−0·89	+5·37	+·040		354·63
8	164·12	+1·41	−2·24	+4·46	+·038		359·76
9	176·31	+1·42	−3·55	+3·36	+·037	+·024	4·97

Greenwich Midnight. 1906.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Physical Libration. Long.	Physical Libration. Lat.	C.
	°	°	°	°	°	°	°
Oct. 10	188·50	+1·42	−4·73	+2·10	+·037	+·024	10·
11	200·69	+1·43	−5·71	+0·72	+·037		14·
12	212·89	+1·44	−6·37	−0·72	+·036		18·
13	225·09	+1·44	−6·65	−2·17	+·035		21·
14	237·30	+1·45	−6·47	−3·55	+·035		23·
15	249·51	+1·45	−5·82	−4·76	+·035		24·
16	261·73	+1·46	−4·71	−5·72	+·036		23·
17	273·94	+1·46	−3·22	−6·32	+·037		21·
18	286·16	+1·47	−1·49	−6·51	+·038		18·
19	298·37	+1·48	+0·32	−6·26	+·039		13·
20	310·58	+1·48	+2·05	−5·58	+·040		7·
21	322·78	+1·49	+3·57	−4·54	+·041		1·
22	334·98	+1·50	+4·78	−3·23	+·042		354·
23	347·16	+1·50	+5·65	−1·74	+·044		349·
24	359·35	+1·51	+6·18	−0·18	+·044		344·
25	11·52	+1·52	+6·40	+1·35	+·045		340·
26	23·68	+1·52	+6·35	+2·78	+·045		337·
27	35·85	+1·53	+6·08	+4·04	+·045		335·
28	48·00	+1·53	+5·63	+5·08	+·045		335·
29	60·16	+1·53	+5·01	+5·85	+·044		336·
30	72·30	+1·53	+4·25	+6·35	+·043		338·
31	84·45	+1·54	+3·35	+6·53	+·042		340·
Nov. 1	96·60	+1·53	+2·31	+6·43	+·040		344·
2	108·74	+1·53	+1·14	+6·04	+·038		348·
3	120·89	+1·53	−0·13	+5·38	+·037	+·024	353·
4	133·04	+1·52	−1·48	+4·50	+·035	+·023	358·
5	145·20	+1·52	−2·86	+3·43	+·033		3·
6	157·36	+1·51	−4·20	+2·20	+·032		8·
7	169·52	+1·51	−5·43	+0·87	+·030		13·
8	181·69	+1·50	−6·47	−0·53	+·029		17·
9	193·87	+1·49	−7·21	−1·94	+·028		20·
10	206·04	+1·49	−7·55	−3·29	+·028		23·
11	218·23	+1·48	−7·43	−4·51	+·028		24·
12	230·42	+1·47	−6·80	−5·51	+·028		24·
13	242·62	+1·46	−5·65	−6·21	+·028		22·
14	254·82	+1·45	−4·04	−6·51	+·028		19·
15	267·02	+1·45	−2·09	−6·38	+·029		15·
16	279·22	+1·44	+0·01	−5·80	+·030	+·023	10·

Greenwich Midnight. 1906.	Selenographical Colong. of the Sun. °	Lat. °	Geocentric Libration. Sel. Long. of the Earth. °	Lat. °	Physical Libration. Long. °	Lat. °	C. °
Nov. 17	291·42	+1·44	+2·07	−4·80	+·031	+·023	3·97
18	303·61	+1·43	+3·92	−3·48	+·032		357·39
19	315·80	+1·42	+5·42	−1·94	+·033		351·06
20	327·99	+1·41	+6·51	−0·33	+·033		345·51
21	340·17	+1·41	+7·16	+1·27	+·034		341·09
22	352·34	+1·40	+7·42	+2·75	+·034	+·023	337·95
23	4·50	+1·39	+7·32	+4·04	+·035	+·022	336·12
24	16·66	+1·38	+6·93	+5·10	+·035		335·52
25	28·81	+1·37	+6·29	+5·89	+·033		336·06
26	40·96	+1·36	+5·47	+6·40	+·032		337·62
27	53·10	+1·34	+4·50	+6·60	+·031		340·09
28	65·24	+1·33	+3·41	+6·51	+·030		343·38
29	77·37	+1·31	+2·22	+6·24	+·028		347·38
30	89·51	+1·30	+0·96	+5·50	+·026		351·95
Dec. 1	101·64	+1·28	−0·36	+4·62	+·024		356·93
2	113·78	+1·26	−1·72	+3·55	+·022		2·15
3	125·92	+1·24	−3·08	+2·31	+·020		7·26
4	138·06	+1·22	−4·39	+0·97	+·018		12·11
5	150·20	+1·20	−5·58	−0·42	+·017		16·42
6	162·35	+1·18	−6·60	−1·82	+·015		19·96
7	174·50	+1·16	−7·35	−3·17	+·014		22·57
8	186·66	+1·14	−7·77	−4·39	+·013		24·09
9	198·83	+1·12	−7·76	−5·42	+·013	+·022	24·42
10	211·00	+1·10	−7·28	−6·18	+·014	+·021	23·51
11	223·20	+1·08	−6·30	−6·60	+·014		21·27
12	235·36	+1·06	−4·85	−6·61	+·015		17·70
13	247·55	+1·04	−3·02	−6·17	+·015		12·87
14	259·74	+1·02	−0·95	−5·30	+·015		6·99
15	271·93	+1·00	+1·18	−4·03	+·016		0·43
16	284·12	+0·98	+3·18	−2·49	+·017		353·78
17	296·31	+0·96	+4·91	−0·80	+·019		347·66
18	308·50	+0·95	+6·24	+0·91	+·019		342·58
19	320·68	+0·93	+7·13	+2·51	+·019		338·86
20	332·85	+0·91	+7·58	+3·92	+·019		336·55
21	345·02	+0·89	+7·60	+5·07	+·018		335·59
22	357·18	+0·87	+7·26	+5·93	+·018		335·85
23	9·34	+0·84	+6·60	+6·49	+·017		337·18
24	21·49	+0·82	+5·71	+6·74	+·016	+·021	339·45

Greenwich Midnight.	Selenographical Colong. of the Sun	Lat. of the Sun	Geocentric Libration. Sel. Long. of the Earth.	Lat. of the Earth.	Physical Libration. Long.	Lat.	
1906. Dec. 25	33°·63	+0°·79	+4°·63	+6°·69	+°·015	+°·021	34
26	45·77	+0·77	+3·42	+6·34	+·012	+·020	34
27	57·91	+0·74	+2·13	+5·72	+·010		35
28	70·04	+0·72	+0·80	+4·86	+·008		35
29	82·17	+0·69	−0·54	+3·80	+·007		[illegible]
30	94·30	+0·66	−1·86	+2·56	+·004		[illegible]
31	106·43	+0·63	−3·12	+1·20	+·002	+·020	1

The longitudes are reckoned in the plane of the Mo equator, the axis of reference being the radius which pa through the mean centre of the visible disc. This axis theref rotates with the Moon, and is not fixed in space.

The inclination of the Moon's equator to the ecliptic is tal as 1°·523, the value used in the *Nautical Almanac*.

The physical librations in longitude and latitude, as given Professor Franz's formulæ, have been applied; their values also printed separately, so that those who prefer to use Hay coefficients (*Ast. Nach.* 3956) can do so. His longitude coeffici is about one-quarter of Franz's. Thus to reduce to Hay value we apply three-quarters of the printed physical librati in longitude with its own sign to Sun's colongitude, and w reversed sign to selenographical longitude of the Earth.

The colongitude of the Sun is 90° (or 450°) *minus* selenographical longitude. It is numerically equal to the sele graphical longitude of the morning terminator reckoned eastwa from the mean centre of the disc. Hence its value is appro mately 270°, 0°, 90°, 180° at new moon, first quarter, full mo last quarter respectively. The longitude of the evening tern nator is of course 180° greater or less than that of the morni one.

When the geocentric libration in longitude is positive, t region brought into view is on the west limb; when negative, the east.

When the geocentric libration in latitude is positive, t region brought into view is at the Moon's north pole; wh negative, at the south.

C denotes the geocentric position-angle of the northe extremity of the Moon's axis measured eastward from t northernmost point of the disc. It has been computed by t second formula given in the Preface to the *Nautical Almanac*.

The terms "East" and "West" are used throughout wi reference to our sky, and not as they would appear to an observ on the Moon.

I give the method for finding the altitude of the Sun at given point on the Moon whose position is defined: (1) l selenographical longitude and latitude; (2) by direction cosines

In either case the Sun's selenographical colongitude and latitude (K, L supposed) must be found by interpolation from the ephemeris for the given time.

In the first case let the given point be in the position longitude M, latitude N. Longitudes are reckoned from the meridian passing through the mean centre of the disc, and the positive direction is that towards the Mare Crisium. North latitudes are considered positive.

Then

$$\text{sine Sun's altitude} = \sin L \sin N + \cos L \cos N \sin (K + M)$$

In the second case let ξ, η, ζ be the direction cosines of the given point. The axes are (1) that diameter of the Moon's equator which is 90° from the mean centre of the disc; (2) the Moon's polar axis; (3) the diameter through the mean centre of the disc. The positive directions are as above. Mr. Saunder has issued some maps of portions of the Moon's surface from which the coordinates ξ, η, ζ can be taken at sight.

Then the Sun's direction cosines are:

$$\cos K \cos L, \sin L, \sin K \cos L,$$

and sine Sun's altitude

$$= \xi \cos K \cos L + \eta \sin L + \zeta \sin K \cos L.$$

Neither formula is convenient when the Sun's altitude is very great, for an angle near 90° cannot be accurately determined from its sine. However, when the Sun is high the shadows are so inconspicuous that it is not necessary to compute his altitude with great accuracy.

The present ephemeris brings to an end the series of Physical Ephemerides in the *Monthly Notices*, as from the commencement of 1907 they are printed in the *Nautical Almanac*. An exception may be made in the case of the *Saturn* ephemeris, which is not printed there, and which I shall continue in the *Monthly Notices* if it appear to be of use to observers.

Benvenue, 55 *Ulundi Road*, *Blackheath*, *S.E*:
1905 *July* 25

[This title is supplied for those who wish to bind separately the Lists of Additions to the Library that have appeared in Vols. LIX. to LXV. of the *Monthly Notices.*]

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1905.

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OF THE

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September, 1905.

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4	*ALDIS, WM. STEADMAN, M.A., F.R.A.S.	Old Headington, Oxford.
8	ALDRIDGE, GEORGE - -	Boston Road, Auckland, New
0	ALEXANDER, WILLIAM - -	7, Burlington Gardens, Acton,
0	ALEXANDER, W. T. - - -	Crummock, Eccles, nr. Manch
8	ALLAN, REV. JAMES - - -	The Manse, Bannockburn.
5	ALLEN, ARTHUR CLEMENT - -	The Preparatory School, Carlisle.
8	ALLEN, ASHTON CHARLES, F.R.A.S.-	Colonnade House, Blackheath
0	ALLEN, REV. G. C. - - -	Cranleigh School, Surrey.
9	*ANDERSON, MRS. EDITH -	193, Woodstock Road, Oxford
8	§§ANDERSON, EDWARD - -	39, Temple Court, Collins Str bourne, Australia.
8	‡ANDERSON, JOHN - - -	Bible Training Institute, 64, Street, Glasgow.
8	*ANDREWS, WILLIAM, J.P., F.G.S. -	Steeple Croft, Coventry.
	Antoniadi, Eugene Michael, F.R.A.S., Director of Mars Section.	74, Rue Jouffroy, Paris.
1	ANTONIADI, MADAME - -	74, Rue Jouffroy, Paris.
8	APLIN, MISS HARRIET - -	Holy Cross Home, Hayward's
	ARCHENHOLD, F. S., Director der Treptow-Sternwarte.	Treptow, bei Berlin.
5	ARCHIBALD, JAMES - -	Hazelbank Villa, Mansfield,

Date of Election.		
1894, Nov. 1	Armstrong, Frank	88 and 90, Deansgate, Manches
	Ash, Arthur Edward	5, Kensington Palace Gardens.
1898, Feb. 23	Astbury, Thomas Hinsley	Croft Villas, Wallingford.
1896, Mar. 25	Attkins, Ernest A. L.	16, Victoria Cottages, Archway Highgate, N.
1892, Nov. 30	Avenell, George	Rose Lodge, Well Walk, Ham N.W.
1896, Nov. 25	Aylett, Ernest George	Bredgar, Sittingbourne, Kent.
1901, Dec. 18	Ayres, Thomas, M.Sc., F.R.A.S.	St. John's College, Battersea, S
	Backhouse, Thomas William., F.R.A.S.	West Hendon House, Sunderla
	Bacon, Miss Gertrude	Cold Ash, Newbury.
	*Bagster, John, F.C.A.	Brookend, Bishop's Stortford, E
	Baikie, Rev. James, F.R.A.S.	Free Church Manse, Ancrum burghshire, N.B.
1904, Nov. 30	Baily, Francis	St. Heliers, Calton Road, D S.E.
1897, May 26	§§Baker, Henry Herbert	78, Swanston Street, Mel Australia
1897, May 26	§§Baldwin, R.	Mollison Street, Kyneton, V Australia.
1896, May 27	Ball, John J.	Charnwood, Court Lane, Dulwi
1892, Dec. 28	*Ball, Sir Robert Stawell, M.A., LL.D., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry, and Director of the University Observatory.	Cambridge.
	Baly, F. D. C.	Bank of England, E.C.
1895, Nov. 27	Banaster, Major George, F.R.A.S.	Bay View, Ramsey, Isle of Ma
1905, June 28	Bangay, Richard	Blockley House, North Finchle
	Bannin, Rev. J. P.	Italian Church, Hatton Garden,
1891, May 27	Baracchi, Pietro, F.R.A.S.	Observatory, Melbourne, Austr
1895, Mar. 27	Barker, Samuel, F.R.A.S.	Grayswood Tower, Haslemere.
	*Barnard, Edward Emerson, M.A., D.Sc., F.R.A.S.	Yerkes Observatory, William Wisconsin, U.S.A.
1899, Jan. 25	Barnard, Henry Osmund, F.R.A.S.	Surveyor-General's Office, C Ceylon.
1901, Nov. 14	§§Barnard, Robert James Allman, M.A.	171, Sydney Road, Brunswic toria, Australia.
	Bassett, J.	82, High Street, Stoke Newingt
	Bateman, John H.	1, York Road, West Norwood,
1898, Jan. 26	Batty, Rev. B. Staunton, M.A.	Medmenham Vicarage, Marlow.
1895, Nov. 27	Bawtree, Bernard Francis	Worcester Road, Sutton, Sur
1891, Nov. 25	Baxendell, Rev. Edwin	12, Lime Grove, Handsw ningham.

Date of Election.		
	BAXENDELL, JOSEPH, F.R.Met.S. -	16, Burlington Road, Birkda port.
1899, Oct. 17	§BAYLDON, FRANCIS J. - -	Booth Street, Balmain, N.S.V
1903, Nov. 25	BAYLIFFE, JOHN HENRY - -	92, Eastern Road, Romford,
1900, Mar. 28	BAZLEY, SIR THOMAS S., BART., M.A., J.P., D.L.	Winterdyne, Bournemouth W
1895, Apr. 24	BEALE, SEYMOUR H. - -	Municipal School of Science Marlborough Road, Banbu
1905, May 16	§BEATTIE, E. H. - - -	Ben Boyd Road, Neutral Ba N.S.W.
	BEAVEN, EDWIN S. - -	5, Boreham Terrace, Wi Wilts.
1894, Nov. 12	‡BECKER, LUDWIG, Ph.D., F.R.A.S., F.R.S.E., Professor of Astronomy in the University.	The Observatory, Glasgow.
	BEDFORD, EDWIN J. - - -	Moorcliff, Redcar Road, Cro Sheffield.
1895, Apr. 25	§BEDFORD, CAPT. JOHN H. - -	Marine Board of New Sout Sydney.
1901, Mar. 27	BEILBY, ERNEST LORAINE - -	74, Loughboro' Road, West Notts.
	§BELFIELD, A. H. - - -	Eversleigh, Dumaresq, Ne Wales.
1904, Oct. 26	BELL, ALBERT H., B.Sc. - -	Municipal Technical Schoo Street, Birmingham.
1902, Dec. 31	BELL, F. AUGUSTUS - -	Old Whyly, East Hoathly, S
1904, Jan. 27	BELL, JOHN HIND, F.R.A.S. -	H.M. Nautical Almanac Verulam Buildings, Gr W.C.
1901, Dec. 18	BELL, MRS. REBECCA - -	77, Manor Road, Brockley, S
1902, Mar. 26	BELLAMY, H. J. - - -	5, Richmond Road, Cambrid
1891, Nov. 25	BENN, ALFRED W. - -	Il Ciliegio, San Gervasio, Italy.
1902, Apr. 30	BENNETT, WILLIAM SHADRACH STONE	59, Mallams, Portland, Dors
1899, Nov. 29	BENSON, REV. J. G. - - -	Wesley House, South Bank Yorkshire.
	BENSON, W. A. S., M.A. - -	39, Montagu Square, W.
1894, Dec. 12	‡BERGIUS, WALTER - -	8, Marlborough Terrace, K Glasgow.
1904, Nov. 30	BEST, REV. JOHN HENRY, B.Sc. -	The Rectory, Stanningley, L
1896, Nov. 25	BEVAN, MRS. M. SOFIA - -	46, Queen's Gate Terrace, S.
1892, Mar. 30	BIANCO, OTTAVIO ZANOTTI - -	Via della Rocca 28, Turin, It
1904, Oct. 1	§BICKERTON, PROF. A. W. - -	Wainomi Park, Christchur Zealand.
1894, Feb. 28	BICKHAM, SPENCER HENRY, J.P., F.L.S.	Underdown, Ledbury.
1903, Oct. 28	BIENE, JOSH. H. VAN - -	No address.
1891, Feb. 25	**BIGG-WITHER, LIEUT.-COL. ARCHIBALD C., F.R.A.S.*	Tilthams, Godalming, So
1895, Oct. 30	BIRD, E. G. - - - -	Sintaluta, Assa., Can

Date of Election.		
1898, Nov. 30	Bird, Rev. J. T., Chaplain to H.M. Forces.	Winterbourne Earls, Salisbury.
	Bischoffsheim, Raphael Louis, F.R.A.S.	3, Rue Taitbout, Paris.
1899, Dec. 27	Bishop, Major Alfred Conway -	61, Rutland Gate, S.W.
1893, Feb. 22	*Bivar, C. S. - - - -	Cinnamara, P.O., Sibsagar, India.
1891, Apr. 29	Blaikie, Walter Biggar - -	c/o T. & A. Constable, 11, Street, Edinburgh.
1898, Apr. 27	Blow, Alfred Lister, F.C.A., F.R.M.S.	11, St. James Court, Buck Gate, S.W.
1904, Nov. 30	Blundell, Oscar - - -	The Manse, Bechis, Central New Zealand.
1901, Apr. 24	Boden, Edward Chambers - -	Clyderhoe, Alexandra Cr Ilkley.
	Boeddicker, Dr. Otto - -	Birr Castle Observatory, Birr, I
1892, Nov. 30	Bogen, Charles Henry - -	66, Hamilton Street, Grimsby.
1900, Dec. 19	Boger, Walter D. - - -	Wolsdon, Antony, Devonport.
1899, Dec. 27	Bolton, Scriven, F.R.A.S. - -	24, Kensington Terrace, Hyde Leeds.
1901, Jan. 30	Bourget, Henry, D. ès Sc., F.R.A.S.	20, Rue St. Jacques, Toulouse.
1894, Nov. 28	Bouton, Vincent Joseph, B.Sc., F.R.A.S.	9, Lansdowne Terrace, Hamptor
1902, Oct. 1	§Bowen, Alexander - -	Currawinya, Fig Tree Point, B N.S.W.
1901, Mar. 27	Bowen, The Hon. Maxwell Steele	Savile Club, Piccadilly, W.
	Bower, James G., Junr. - -	Earlham House, Norwich.
1892, Jan. 27	Bowman, John Herbert - -	Greenham Common, Newbury.
1895, Jan. 9	Brand, William Norman - -	Calle Rivera, 121, Buenos Ayre
	Brashear, John A., F.R.A.S. - -	Allegheny, Pa., U.S.A.
	*Brennan, Rev. M. S. - -	St. Lawrence's Church, 14 O'Fallon Streets, St. Loui U.S.A.
1894, Jan. 31	Brenner, Leo - - -	Manora - Sternwarte, Lussin Istrien.
1892, Nov. 30	Brent, Thomas George Gloster -	81, Long Lane, Aldersgate, E.C
1896, June 24	Brester, Dr. A. - - -	Delft, Holland.
1896, Nov. 25	Bridger John Henry, Mus.B. -	Lyndhurst, Farnborough, Hant
1899, May 31	*Bridges, Rev. Guy, F.R.G.S., F.R.Met.S.	Sutton Mandeville Rectory, Salisbury.
1894, Nov. 1	Bright, John Albert, J.P. - -	One Ash, Rochdale.
1893, Nov. 29	Broad, Samuel - - -	170, New North Road, N.
1892, Oct. 26	Broadbent, William - -	Central Ironworks, Huddersfiel
1898, Oct. 26	Brocklebank, Clement Edmund Royds.	The Roscote, Heswall, Cheshir
1894, Mar. 28	Broderip, Edmund - -	Manor House, Cossington, water.
1898, Feb. 23	*Brodie, Charles Gordon, F.R.C.S.	Fern Hill, Wootton Bridge, Wight.
1902, Nov. 26	*Brodie, Mrs. Hugh Kinsman -	Villa Beatrice, S. Remo, Italy.
1900, Dec. 19	Brook, Mrs. Arthur -	Woodhouse, Weybridge.

Date ' Election.		
9, June 28	*Brook, Charles Lewis, M.A., F.R.A.S., F.R.Met.S.	Harewood Lodge, Meltham, H field.
1, Apr. 29	*Brooks, Joseph, F.R.G.S., F.R.A.S.	Hope Bank, Nelson Street, Wo viâ Sydney, N.S.W.
	Brough, James R. - - -	Eversley, 29, Alexandra Villas bury Park, N.
9, Nov. 29	Brown, Miss J. E. A. - -	Further Barton, Cirencester.
	Brown, Leonard J. - -	12, Eastbourne Terrace, Padding
	*Browne, James Stark, F.R.A.S. -	The Red House, Mount Avenue,
	Bruce, The Right Hon. Sir Gainsford, F.R.A.S.	Yewhurst, South Hill, Bromley,
9, May 31	Bruford, George - - -	Tolland House, Shoot-up Hill, (wood, N.W.
9, Nov. 29	Buchanan, W. E. - - -	Water Works, Simla, India.
5, May 4	§§Bugg, Samuel - -	Piper Street, Kyneton, Victori tralia.
5, Mar. 1	§Bulkeley, Richard H. - -	Wallerawang, N.S.W.
9, June 28	*Bullock, John, M.A. - -	4, Leamington Villas, Chiswicl W.
0, Jan. 31	*Burns, Gavin James, B.Sc. - -	Building Works Department, Arsenal, Woolwich.
4, Dec. 19	Burton-Brown, Col. Alexander, R.A., F.R.A.S., F.G.S.	11, Union Crescent, Margate.
2, Apr. 27	Bush, Thomas Charles, F.R.A.S. -	Elm Bank, Bloomfield Road, B
2, Apr. 12	Buss, Albert Alfred - -	9, Grosvenor Square, Ash Mersey, near Manchester.
	Buttemer, R. W. - -	St. Mary's, near Godalming.
5, Dec. 18	§§Byatt, John - - -	7, Mary Street, Grace Park, thorne, Victoria, Australia.
1, Feb. 25	Byrd, Miss Mary E., Director of Smith College Observatory.	Northampton, Mass., U.S.A.
0, Nov. 28	Cafferata, Louis W. - -	Staunton Hall, Orston, Notts.
2, Nov. 30	Calmady, Charles Calmady -	Stoneycroft, Horrabridge, Devon.
	Calver, George, F.R.A.S. - -	The Manse, Walpole, Hal Suffolk.
), Apr. 5	§§Cameron, John N. - -	3, Flinders Court, Melbourn tralia.

Date of Election.		
1903, Feb. 26	‡CAMPBELL, ARCHIBALD - -	Park Lodge, 62, Albert Drive, P shields, Glasgow.
1905, Feb. 6	§CAMPBELL, MURRAY - -	c/o G. J. Cobb, Calala, West] land, N.S.W.
1897, Jan. 27	CAPRON, FREDERICK HUGH, F.R.A.S.	156, Leadenhall Street, E.C.
1902, Nov. 26	CAREY, CHARLES MACLEOD - -	Drynoch House, New M Surrey.
1900, Feb. 28	CARPENTER, CAPT. ALFRED, R.N., D.S.O., F.R.Met.S.	The Red House, Sanderstead, Cro
	CARR, REV. CANON EDMUND, F.R.M.S., F.R.Met.S.	Holbrooke Hall, near Derby.
1899, May 31	*CARTER, CHARLES ERNEST O. -	The Hermitage, Parkstone, Dors
1895, Nov. 6	CARVER, BENJAMIN - - -	Polefield House, Prestwich, near chester.
1897, Nov. 24	*‡CASSELLS, MAJOR JOHN, V.D., J.P., F.R.A.S.	154, Queen's Drive, Crosshill, gow.
1894, Dec. 19	CASTLEDEN, REV. G. - - -	Dennington Rectory, Framlingha
1897, June 30	CAVAN, JAMES, M.A., F.R.A.S. -	Eaton Mascott Hall, near Shrews
1892, Mar. 30	*CEBRIAN, J. C. - - -	N.W. Cor. Pine and Octavia St San Francisco, U.S.A.
	CHAMBERS, B. E. C. - - -	Grayswood Hill, Haslemere.
	CHAMBERS, GEORGE FREDERICK, F.R.A.S.	Lethen Grange, Sydenham, S.E.
1891, May 27	CHAMP, HENRY - - -	c/o S. & J. Watts & Co., Manche
	CHAPMAN, PALMER - -	Old Haywoods, Deepcar, near She
1898, Feb. 23	§§CHAPPLE, REV. EDWARD HENRY -	Wesleyan Parsonage, Lanc Victoria, Australia.
1897, June 30	CHATWOOD, SAMUEL, F.R.A.S. -	High Lawn, Worsley, near Manch
1900, Apr. 25	CHILD, JOHN WALLER LAURENCE, F.R.A.S.	Fishing Lake, P.O., Yorkton, Canada.
1891, Nov. 25	CHILDE, EDGAR AUGUSTUS - -	London, City, and Midland Bank, 71a, Queen Victoria Street, E.(
	CHURCHILL, LORD EDWARD SPENCER, F.R.A.S.	28, Grosvenor Street, W.
1899, Nov. 29	CLARET, JOHN CHARLES - -	Moulton, Northamptonshire.
1897, Nov. 24	CLARIDGE, REV. JOHN THOMAS WINDMILL, M.A., F.R.A.S.	42, Edgbaston Road, Moseley, mingham.
1897, May 26	§§CLARK, E. R. - - -	255, Amos Street, North Ca Victoria, Australia.
1893, Oct. 25	CLARK, JAMES EDMUND, B.A., B.Sc. -	Milton House, 8, Chiswell Street,
	CLARKSON, A. - - - -	28, West Side, Wandsworth Con S.W.
1898, Nov. 30	CLAXTON, THOMAS FOLKES, F.R.A.S., Director of the Royal Alfred Observatory.	Mauritius.
1892, May 10	CLAYTON, JAMES - - -	177, Park Lane, Macclesfield.
	CLERKE, MISS AGNES M., Hon. Memb. R.A.S.	68, Redcliffe Square, S.W.
1905, Feb. 22	CLIPSHAM, KENNETH M. - -	15, Spencer Avenue, Toronto, Ca
1895, Mar. 1	§CLOSE, T. H. - - -	Existing Lines Department, Br Street, Sydney, N.S.W.
1903, June 24	CLOUGHER, T. R. - -	225, Strand, W.C.

Date of Election.		
1899, Oct. 1	§§Coane, Henry Edward	70, Queen Street, Melbourne, Australia.
1901, Mar. 19	§Cobham, Allan B.	c/o Australian Mutual Provident Society, 67, Pitt Street, Sydney, N.S.W.
1898, Nov. 29	*Cochrane, A. Stanley	c/o W. N. Cochrane, 10, Hogarth Road, Earl's Court, S.W.
	Coleman, William, F.R.A.S.	The Shrubbery, Buckland, Dover.
1893, Feb. 22	Collenette, Adolphus, F.C.S.	Brooklyn, Fort Road, Guernsey.
	Collings, Chas. A.	60, Wyatt Road, Forest Gate, E.
1894, Oct. 31	Collins, C. E.	Thorncliff, Wadebridge, Cornwall.
1897, May 26	Comas, José Sola, F.R.A.S.	29, S. Felipe, S. Gervasio, Barcelona, Spain.
1903, Oct. 28	*Comber, Thomas S.	Leighton Brow, Neston, Cheshire.
1904, Jan. 28	‡Contreras, Don Manuel de	131, West Regent Street, Glasgow.
1904, Mar. 30	Conway, Rev. H.	The Oxford Mission House, 42, Cornwallis Street, Calcutta.
1893, Feb. 22	Cook, Truman J.	Rydal Mount, Bodenham Road, Hereford.
1900, Oct. 31	Cooke, Conrad W.	Rothley, Macaulay Road, Clapham Common, S.W.
	*Cooke, James S.	c/o Mrs. J. W. Parker, 13, Vernon Road, Heckmondwike, Yorkshire.
1899, Dec. 27	Cooke, Capt. Uriah	108, Waller Road, New Cross, S.E.
1892, Apr. 27	Cookson, Bryan, M.A., F.R.A.S.	2, Devana Terrace, Cambridge.
1905, Apr. 26	Cooper, Harry	40, Robertson Road, Eastville, Bristol.
1892, Nov. 30	Cope, Edward J.	Mendip, West Malvern.
	Copeland, Ralph, Ph.D., F.R.A.S., F.R.S.E., Astronomer Royal for Scotland.	Royal Observatory, Blackford Hill, Edinburgh.
	Corder, Henry	Silver Birch, Bridgwater.
1895, Jan. 10	Core, Prof. Thomas H., M.A.	Groombridge House, Withington, Manchester.
1894, Nov. 28	***Cortie, Rev. Aloysius L., S.J., F.R.A.S., Director of Solar Section.**	Stonyhurst College Observatory, Blackburn, Lancashire.
	Cottam, Arthur, F.R.A.S.	Furze Bank, Durleigh Road, Bridgwater.
1902, Dec. 31	Cotton, Rev. James W.	Beacham House, South Terrace, South Bank, R.S.O., Yorkshire.
1901, May 29	Cotton-Jodrell, Colonel Edward Thomas Davenant, C.B.	Reaseheath Hall, Nantwich.
1903, Dec. 30	Courtney, Miss Dorothy S.	104, Redland Road, Bristol.
1901, Dec. 18	Coventry, Philip H.	36, Laurel Road, Fairfield, Liverpool.
1901, Oct. 30	Cowan, Frederic Justus Herbert, LL.D.	Department of Justice, Batavia.
1897, Oct. 27	*Cowell, Philip, M.A., F.R.A.S.	Royal Observatory, Greenwich, S.E.
1904, Mar. 30	Cowley, H. T.	10, Algiers Road, Ladywell, Lewisham, S.E.
	*Cox, W. H.	Royal Observatory, Cape Town, S. Africa.

Date of Election.		
	Craig, Rev. S. Runsie, B.A., LL.B., F.R.A.S.	The Rectory, Moville, Londonderry.
1902, June 17	§Cran, Robert - - -	Neutral Bay, Sidney, N.S.W.
1896, Mar. 25	Cranfield, John George - -	Burstall, Suffolk.
	Crawford, Tyson, F.R.A.S. -	Arundel Lodge, Sidcup.
1904, Jan. 27	Cripps, Frederick Richard -	22, Hornsey Rise Gardens, N.
	Criswick, George S., F.R.A.S. -	6, Montpelier Row, Blackheath, S.E.
1899, Nov. 29	Croke, Edward Thomas - -	Innisfallen, 1, New Parade, Worthing.
1895, Nov. 27	**Crommelin, Andrew C. D., B.A., F.R.A.S., President.**	Benvenue, 55, Ulundi Road, Blackheath, S.E.
1900, Feb. 28	Crommelin, Mrs. - -	Benvenue, 55, Ulundi Road, Blackheath, S.E.
1892, Nov. 30	Cross, Robert - - -	210, Banbury Road, Oxford.
1902, Apr. 15	§Crossman, A. - - - -	Armidale, N.S.W.
1891, Nov. 25	Crowley, Lewellin Applin -	128, Avenue de Neuilly, Neuilly-s.-Seine, France.
1898, Apr. 27	*Cullum, Ernest Alfred Nelson -	Rosslyn, 30, Humber Road, Blackheath, S.E.
	Cumes, George, F.R.G.S. - -	113, Hopton Road, Streatham, S.W.
	Cunningham, Miss Susan J. - -	Swarthmore College, Delaware Co., Penn., U.S.A.
1898, Jan. 26	Curties, Charles Lees - -	244, High Holborn, W.C.
1900, Dec. 19	Curtis-Hayward, Arthur Cecil -	21, Bedford Row, W.C.

1905,	§Dale, A. H. - - - -	Stemington, Rose Street, Chatswood, N.S.W.
1904, Oct. 26	Daniell, Mrs. Averell - -	12, Cadogan Mansions, S.W.
1895, Jan. 9	*‡Dansken, John, I.M., F.S.I., F.R.A.S.	2, Hillside Gardens, Partick-hill, Glasgow.
1894, Jan. 31	Darby, Very Rev. John L., D.D. -	The Deanery, Chester.
1896, Oct. 20	Darley, Cecil West, M.Inst.C.E. -	34, Campden Hill Court, Campden Hill Road, Kensington, W.
1903, Dec. 30	Daunt, Capt., R.A.C., D.S.O. -	Lynalta, Newtownards, Co. Down.
1891, Apr. 29	*Davidson, J. Ewen - -	98, Banbury Road, Oxford.
	Davies, Rev. Charles D. P., M.A., F.R.A.S.	Fretherne, Stonehouse, Gloucestershire.
1892, Dec. 28	*Davies, Lieut. F. J. - - -	Guards' Club, Pall Mall, S.W.
	Day, A. C. - - -	Beachville, Oak Street, Deal.
	*Day, Richard Evan, M.A., F.R.A.S.	Culver, Plaistow Lane, Bromley, Kent.
1902, Nov. 20	§Deane, Miss Edith - -	Lindcourt, Lindfield, N.S.W.
1902, Mar. 26	Demeille, Maurice - -	92, Rue de la Trésorerie, Bordeaux, France.
1898, Oct. 26	Denning, William Frederick, F.R.A.S.	44, Egerton Road, Bishopston, Bristol.

Date of Election.		
Nov. 28	DESLANDRES, HENRI, D. ès Sc., A.R.A.S.	Observatoire, Meudon, Seine-et-Oise, France.
Jan. 18	§DEVEY, ALFRED JOHN - -	Porchester Street, Newcastle, N.S.W.
Apr. 29	DICKSON, EDMUND, F.G.S. - -	2, Starkie Street, Preston.
Apr. 29	DICKSON, THOMAS ARTHUR - -	Sywell Hall, Northampton.
Nov. 25	DIXON, MISS ELIZABETH KATHARINE	16, Mount Pleasant, Darlington.
Nov. 25	*DIXON, GEORGE - - -	St. Bees, Cumberland, and Trinity College, Cambridge.
	DIXON, DR. JOHN - -	133, Jamaica Road, Bermondsey, S.E.
Mar. 19	§§DOBBIE, A. W. - - -	Rothsay Villa, College Park, Adelaide, South Australia.
Apr. 26	DOBIE, WILLIAM MURRAY, M.D., J.P., F.R.A.S.	Northgate House, Chester.
Jan. 31	DODD, WILLIAM BRAYTON - -	10, Brockholes View, Preston, Lancashire.
Jan. 27	DOLMAGE, CECIL GOODRICH JULIUS M.A., LL.D., D.C.L., F.R.A.S.	38, Warwick Road, Earl's Court, S.W.
May 26	§§DONAHAY, WILLIAM - - -	165, Glenferrie, Hawthorne, Victoria, Australia.
Nov. 24	DONNELLY, PATRICK JOSEPH -	4, Queen Street, Dublin.
	*Downing, Arthur M. W., M.A., D.Sc., F.R.S., F.R.A.S., Past President.	8, Granville Park, Blackheath, S.E.
Nov. 19	DRUMMOND, L.S., F.S.A.A. - -	Australasia Chambers, Martin Place, Sydney, N.S.W.
Mar. 27	DUGARD, WILLIAM H., A.M.I. Mech.E.	Arden House, Blossomfield, Solihull, near Birmingham.
May 5	§§DULFER, CHARLES J. -	Victoria Street, West Melbourne, Australia.
Oct. 28	*DUMAT, FRANK C., F.R.A.S. -	Ægis Buildings, Johannesburg, South Africa.
Feb. 12	*‡DUNLOP, NATHANIEL - - -	1, Montgomerie Crescent, Kelvinside, Glasgow.
Nov. 25	DUNN, REV. JOHN, M.A., D.C.L. -	Road Hill Vicarage, Bath.
Nov. 27	*DYKES, PROF. FREDERICK JAMES -	Royal Naval Barracks, Portsmouth.
Apr. 25	DYSON, FRANK WATSON, M.A., F.R.S., F.R.A.S.	Royal Observatory, Greenwich, S.E.

Jan. 31	EAST, REV. ARTHUR, B.A., Cantab. -	Southleigh Vicarage, Witney, Oxon.
Feb. 25	EDDIE, MAJOR LINDSAY ATKINS, F.R.A.S.	Fitzroy Street, Grahamstown, Cape Colony.
	EDGECOMB, D. W. - -	Mystic, Connecticut, U.S.A.
Mar. 1	§EDMONDS, CAPT. HERBERT HENRY -	Idalia, Longueville, Sydney, N.S.W.
	EDWARDS, REV. W. AUGUSTUS -	Pembroke Dock.

wards, William Saunders -	Thornleigh, Bradpole
d, Rev. Francis John, M.A., F.R.A.S.	Polstead Rectory, Col
iott, Arnold - - -	Yateholme, Winchest ampton.
liott, Ralph - - -	Tokenbury, Liskeard.
lis, Henry, F.R.A.S. - -	Inglefield, Little Heat
llis, Humphrey Cadogan - -	Bothalhaugh, Morpet
lis, William, F.R.S., F.R.A.S., F.R.Met.S.	Montpelier House, Bl
sdaile, Edward, Junr. - -	Hunter Street, Sydney
iatt, Ibraham, Bey - -	Baghala, Saida-Zenab,
pin, Rev. T. H.E.C., M.A., F.R.A.S.	Tow Law, R.S.O., Dar
sam, Edward Iszatt, F.R.A.S., Director of the Coloured Star Section.	Billingborough, Lincol
ans, Cecil Gordon - -	33, Ranelagh Road, W
erett, Miss Alice, M.A. -	13, Weymouth Street, W.
ershed, John, F.R.A.S. - -	Kenley, Surrey.

Date Election.		
	*Forbes, Hon. George Stuart, M.A., I.C.S., F.R.A.S.	c/o King, King, and Co., East India Agents, Bombay.
	Forgan, W. - - -	3, Warriston Crescent, Edinburgh.
Feb. 24	Formoy, James Arthur, F.C.S., F.R.A.S.	Chestham, Grange Road, Sutton, Surrey.
Mar. 29	Forsyth, David, J.P. - -	St. Andrew's Villa, Elgin, N.B.
	Foulkes, Rev. T. H., M.A., Chaplain to H.M. Forces.	17, Fulford Road, York.
	*Fowler, Alfred, F.R.A.S. - -	Royal College of Science, South Kensington, S.W.
, Nov. 30	Fox, Wilson Lloyd, F.R.Met.Sc. -	Carmino, Falmouth.
, Jan. 25	Fraser, John - - -	Lyle's Chambers, 250, Church Street, Pietermaritzburg, Natal.
	French, G. M. - - -	1, Marchwood Crescent, Ealing.
, Feb. 25	Friend, Professor Charles W. -	Carson City, Nevada, U.S.A.
	Gage, W. H. St. Quintin, F.R.A.S. -	High Street, Wolsingham, Darlington.
, Dec. 27	§Gale, Walter F., J.P., F.R.A.S. -	Newcastle, N.S.W.
	Gare, F. - - - - -	Hazelgrove, Staines.
, Apr. 12	Garnett, William, F.R.A.S. -	Low Moor, Clitheroe.
, Nov. 12	‡Garrow, Robert - - -	21, York Street, Glasgow.
, Mar. 26	Gaskarth, Henry - -	26, Howard Street, Bradford.
, Oct. 29	Gaythorpe, Sydney Bertram -	Claverton, Prospect Road, Barrow-in-Furness.
, Nov. 29	Gedge, Rev. A. A. L., B.A. - -	Senior Chaplain's Quarters, Malta.
	Gemmill, S. M. Baird, F.R.A.S. -	c/o W. L. Wilson, 50, Great Western Road, Glasgow.
	Gibbins, William - - -	Beech Hill, Sir Harry's Road, Edgbaston, Birmingham.
, Nov. 24	Gibbs, William Bolger, F.R.A.S. -	Thornton, Beulah Hill, Norwood, S.E.
	Giberne, Miss Agnes A. - -	c/o Messrs. Barclay & Co., Bankers, Terminus Road, Eastbourne.
, Feb. 25	Gill, Sir David, K.C.B., LL.D., F.R.S., F.R.A.S., His Majesty's Astronomer.	Royal Observatory, Cape of Good Hope.
, Jan. 25	Gill, Lady - - - -	Royal Observatory, Cape of Good Hope.
, Apr. 28	§§Gillespie, Robert - -	37, Mary Street, Hawthorne, Victoria, Australia.
, Nov. 30	Gillihan, Allen F., M.D. -	2221, Shattuck Avenue, Berkeley, California, U.S.A.
, June 28	Ginori, Nello Venturi - -	75, Via della Scala, Florence.
	Giovannozzi, Rev. Dr. G., S.P., Director of the Ximenian Observatory.	Florence, Italy.
, Oct. 1	§Givin, Dr. R. D. - -	87, Pitt Street, Sydney, N.S.W.
, Dec. 19	Glass, John - - -	Mill of Migvie, Tarland, Aberdeenshire.
, Jan. 30	Goatcher, Alfred Winton - -	Royal Observatory, Cape of Good Hope.
, Nov. 27	Godby, H. A. – – -	Belford, 167, London Road, Kingston-on-Thames.

Date of Election.	
1899, Oct. 25	Gooch, Miss Emily
	Goodacre, Walter, F.R.A.S., Director of Lunar Section.
1891, Mar. 25	Gordon, Thomas, F.R.Met.S., F.R.A.S.
1893, Dec. 27	Gordon, William Hastings Graham
	Gore, John Ellard, M.R.I.A., F.R.A.S.
1903, Feb. 25	Gower, Alfred William
1894, Nov. 12	Grant, Frank L., M.A., F.R.A.S.
1905, Mar. 16	‡Gray, Andrew, M.A., LL.D., F.R.S., Professor of Natural Philosophy in the University.
1905, May 31	Green, Miss Catherine C.
1902, Oct. 29	Greenaway, Capt. W. T.
1901, June 26	Greenstreet, William John, M.A., F.R.A.S.
1894, June 27	Greenwell, Thomas George
	*Greenwood, John Anderton, B.A., LL.M., F.R.A.S.
1896, May 27	Gregg, Ivo Francis Henry Carr
	Gregory, A.
	Greig, Andrew
	Griffin, Fred. C. G., M.A., M.B.
1903, Oct. 20	§Griffin, J. G., J.P.
1905, Jan. 25	Griffith, Charles Leopold Troyte, A.M.Inst.C.E., Professor of Civil Engineering.
1891, May 27	Griffiths, Richard Fletcher
1897, Dec. 29	Grigg, John
	Grove, Samuel
1892, Mar. 30	Grove, William
	Grover, Charles
	Grubb, Sir Howard, F.R.S., F.R.A.S., M.I.C.E.I.
	*Guinness, Rev. H. Grattan, D.D., F.R.A.S., F.R.G.S., F.R.Hist.S.
	*Gümpel, C. Godfrey, A.I.C.E.
1901, Dec. 18	Gunnis, John W., C.E.

Date of Election.		
1903, Nov. 25	GUYON, MAJOR-GENERAL GARDINER FREDERIC, F.R.A.S.	Egerton House, Richmond, Surrey.
1897, Jan. 27	HADDEN, DAVID E., F.R.A.S. -	Alta (Buena Vista Co.), Iowa, U.S.A.
1900, Oct. 31	HAFFERL, FRANZ - - -	20, Jubiläumstrasse, Mödling, near Vienna, Austria.
1891, May 27	HALE, GEORGE E., D.Sc., F.R.A.S. -	Mount Wilson, California, U.S.A.
1898, Nov. 30	HALL, JAMES P. - - -	6, Poplar Street, Brooklyn, N.Y., U.S.A.
1898, Dec. 28	HALL, JOHN JAMES, F.R.A.S. -	Observatory Cottage, Datchet Road, Slough.
1897, Feb. 24	HALL, WALTER J. - -	c/o Harvey & Sons, Ltd., Peel Tannery, Bury, Lancashire.
1895, Sept. 26	§HALLIGAN, GERALD H., F.G.S., L.S.	Public Works Department, Sydney, N.S.W.
	HALLOWES, GEORGE P. B., F.R.A.S. -	Collingwood, Anglesea Road, Donnybrook, Dublin.
1892, Apr. 27	HAMMOND, FREDERICK, F.R.I.B.A., F.R.A.S.	38, Mercers Road, Holloway, N.
1891, Mar. 25	HAMPTON, THE RIGHT HON. LORD -	Waresley Court, Kidderminster.
1905, June 28	HANBRIDGE, H. R. - -	10, Mehitabel Road, Hackney, N.E.
1902, Oct. 29	***Hardcastle, Joseph Alfred, F.R.A.S., Secretary.**	The Dial House, Crowthorne, Berks.
1900, June 7	§§HARDESS, GEORGE -	183, Moore Street, Moonie Ponds, Melbourne, Australia.
1905, Jan. 19	‡HARDIE, CAPT. JAMES - -	Cintra, Troon, Ayrshire, N.B.
1892, Nov. 30	HARDY, GEORGE FRANCIS, F.I.A., F.R.A.S.	7, Broad Street House, Old Broad Street, E.C.
1903, Nov. 25	HARRIS, W. BAYNARD - -	Te Kowhai, Ngaruawahia, Auckland, New Zealand.
1898, Oct. 6	§§HARTUNG, ERNST - - -	Ostara, Glenearg Grove, Malvern, Melbourne, Australia.
1900, Nov. 28	HARVEY, O. G. - - -	Wanganui, New Zealand.
1893, Oct. 25	HARVEY, WILLIAM - - -	47 Victoria Street, S.W.
1893, Apr. 26	HASTINGS, O. C. - - -	152, Douglas Street, Victoria, British Columbia.
	HASWELL, JOHN, D.C.L. - -	11, Grange Terrace, Sunderland.
	HATCHARD, JOHN GEORGE, F.R.A.S. -	Box 80, Bloemfontein, Orange River Colony, South Africa.
1895, Apr. 24	HATCHARD, MRS. - - -	c/o Miss Hatchard, Brimley House, 24, Montague Hill, Bristol.
1893, Jan. 10	HAUGHTON, WILLIAM A. - -	Vega Cottage, Greenhough Street, Droylsden, near Manchester.
1896, Feb. 26	HAWKES, ALFRED - - -	Exchequer and Audit Department, Victoria Embankment, E.C.
1898, Oct. 26	HEARD, LT.-COL. E. S. - -	Staff College, Camberley, Surrey.
	HEATH, THOMAS - -	Royal Observatory, Edinburgh.
1900, Feb. 28	HEATH, WALTER, M.A., F.R.A.S. -	Uplands, Cobham, Surrey.
	*HEBERT, REV. SEPTIMUS - -	Leafland, Harrow.
1892, Apr. 12	HEENAN, HAMMERSLEY, M.Inst.C.E., M.I.Mech.E., F.M.P.S.	The Manor House, Wilmslow, Cheshire.
1905, *June 28*	*HENDERSON, REV. ALEX. C., B.D.* -	Manse of Delting, Brae, Shetland.

Date of Election.		
1901, Mar. 27	*Henderson, William Patrick	Allahabad, Bengal, India.
1896, Nov. 25	Hepburn, Patrick H.	5, Great Ormond Street, W.C
	‡Herkless, Mrs.	94, Redcliffe Gardens, Ke S.W.
1888, Oct. 25	Hicks, Edward Rupert	67, Holland Road, Kensingto
	Hildersley, James	7, Lupton Street, Kentish To
1895, Mar. 1	§Hirst, George Denton, F.R.A.S.	Berowra, Muston Street, Sydney, N.S.W.
1902, Nov. 26	Hitchings, F.	Sydenham, New Zealand.
1896, Nov. 25	Hodge, Miss Alma	Flat 5, 28, Warrington Maida Vale, W.
1896, Nov. 25	Hodge, Miss P. R.	Flat 5, 28, Warrington Maida Vale, W.
1898, Jan. 26	Hodge, R.	Ruhstein, Grange Road, High
1905, Jan. 25	Hodgkin, George Lloyd	2, The Avenue, Sunderland.
1905, Jan. 25	Hodgkin, Thomas Edward	Whiteknights, Bellgrove, N on-Tyne.
1900, Mar. 28	Hoffmann, Otto	Budapest, V, Nádor utcza, gary.
	*Holden, Prof. E. S., M.A., Sc.D., LL.D., A.R.A.S.	U.S. Military Academy, We New York, U.S.A.
	Holden, Frank J. G., B.A., A.M.Inst.C.E.	c/o Scarborough Electric Su Ltd., Seamer Road, Scarbo
	Holden, Neville, F.R.A.S.	Queen's Square, Lancaster.
1904, Feb. 24	Holderness, S. W.	Shirley, Whytecliffe Road, Surrey.
1893, Oct. 17	Holland, George	5, Monton Road, Eccles, n chester.
1898, Mar. 29	Holland, Philip	87, Tierney Road, Streatham I
	Hollis, Henry Park, B.A., F.R.A.S.	79, Foyle Road, Blackheath,
	Holloway, Rev. Edward J., M.A.	Clehonger Vicarage, Hereford
	Holmes, C.	Primrose Cottage, Buckingha South Woodford.
1900, Dec. 19	Holmes, Charles Bilson	St. George's Villa, Tennys Harpenden.
	Holmes, Edwin	Orleans Villa, Hornsey Rise,
1896, Nov. 25	Holmes, Philip	57, Oxford Gardens, Kensing
1902, Feb. 26	Hopkins, Miss Mary Murray	350, Washington Avenue, I New York, U.S.A.
1896, Nov. 25	Hopman, F. J.	Liliegracht, 10, Amsterdam.
1900, May 30	Horner, Donald William, F.R.Met.S.	Milford Lodge, 82, New Pa Clapham Park, S.W.
1902, Nov. 20	§Hoskins, George, Junior	St. Cloud, Burwood, N.S.W.
1898, Nov. 15	§Hoskins, W., Senior	188, Sussex Street, Sydney, N
1891, May 27	Hough, Prof. G. W., A.R.A.S., Director of the Dearborn Observatory.	Evanston, Ill., U.S.A.
1892, June 21	Houlgate, Rev. W. J.	Tetlon House, Claremont Fleetwood.
1894, Oct. 31	Howarth, Elijah, F.R.A.S.	Public Museum, Weston Pa
1892, May 25	*Howat, William	358, William Street, Mel tralia.

te ction.		
ov. 12	‡HOWE, WILLIAM - - -	12, Queen's Terrace, Ayr.
	HOWLETT, REV. FREDERICK, M.A., F.R.A.S.	7, Princes Buildings, Clifton, Bri
pr. 12	HOY, SIR JAMES, J.P. - -	Heaton Mersey, near Manchester
ec. 17	‡HUBBARD, JOHN JAMES - -	9, Bute Mansions, Glasgow, W.
ec. 17	‡HUBBARD, WALTER R. - -	6, Broomhill Avenue, Partick, Gla
in. 28	HUDSON, PROF. RUBINSTEIN -	Rubinstein, West Kirby, Cheshir
ay 10	HUDSON, THOMAS - - -	The Elms, Elm Grove, Alderley Cheshire.
ov. 28	HUGGARD, WILLIAM R., M.A., M.D. -	Davos Platz, Switzerland.
	HUGGINS, SIR WILLIAM, K.C.B., O.M., Ph.D., LL.D., D.C.L., P.R.S., F.R.A.S.	90, Upper Tulse Hill, S.E.
	HUGGINS, LADY, Hon. Memb. R.A.S. -	90, Upper Tulse Hill, S.E.
ct. 26	HUGGINS, WILLIAM JOHN - -	Timaru, New Zealand.
ay 31	HUGHES, CAPT. F. ST. J. - -	Warash House, Warash, South E
ec. 30	HUGHES, WILFRED HORSFALL -	Kynance, Birkby, Huddersfield.
ct. 31	HUMAN, HENRY - - -	62, Birdhurst Road, Croydon.
pr. 30	HUNT, D. N. - - - -	11. Westbere Road, West Hamp N.W.
une 30	HUNT, WILLIAM M. - - -	48–50, London Road, Nottinghar
ec. 17	‡HUNTER, DAVID, F.R.A.S. - -	St. Ronan's, Lanark.
ec. 20	‡HUNTER, WILLIAM S. - -	Kildonan, Maxwell Drive, P shields, Glasgow.
	HUTCHINGS, REV. ROBERT SPARKE F.R.A.S.	Alderbury Vicarage, Salisbury.
	HUTCHINSON, CUTHBERT, F.R.A.S.	Rock Lodge, Roker, Sunderland.
	HUTT, ALEXANDER - - -	112, Bowes Road, Palmer's Gree
ay 30	INGLE, FREDERICK - - -	24, Queen Anne's Gate, S.W.
pr. 29	INNES, ROBERT THORBURN AYTON, F.R.A.S.	The Observatory, Johanne South Africa.
ov. 30	IRVING-NOBLE, MRS. A. - -	Forest Lodge, Maresfield, Ucl Sussex.
	IZZARD W. H. - -	20, Boston Park Road, Brentford
ov. 12	*‡JACK, WILLIAM, M.A., LL.D., Professor of Mathematics in the University.	10, The University, Glasgow.
pr 30	JACKSON, CECIL - - -	Rycroft Bank, Dore, Sheffield.
	JACKSON, WILLIAM EDWARD - -	Salonica, Turkey.
eb. 28	JACQUES, RICHARD, M.Inst.C.E. -	Caldera, Chile.
eb. 25	*JAFFE, SIR OTTO, F.R.A.S. - -	10, Donegall Square South, Bel
	JAMES, HUGH - - -	Bryn Eos, 85, Nightingale Balham, S.W.

Date of Election.		
	JENKINS, G. P. - - -	Burlington, Ontario, Canada.
1903, Dec. 30	JENKINS, WILLIAM C. - -	Godlee Observatory, Municipal of Technology, Sackville - Manchester.
1896, June 24	JENKINSON, JOHN HENRY - -	Ocklye, Crowborough, Tu Wells.
	*JOBLING, THOMAS EDGAR - -	Bebside, Northumberland.
	*JOHNSON, ERNEST W. - -	50, Birdhurst Road, South Cro
1900, Apr. 25	JOHNSON, Mrs. - - -	50, Birdhurst Road, South Cro
1900, Jan. 31	JOHNSON, RICHARD COWARD, F.R.A.S.	7, Church Road, West Kirby, C
	*JOHNSON, REV. SAMUEL J., F.R.A.S.	The Vicarage, Melplash, R.S.O port, Dorset.
1904, Feb. 24	JOHNSON, W. KNOX, B.A. - -	Education Department, B India.
1895, Dec. 18	JOHNSTON, ARTHUR H. - - -	Alderley, Onslow Gardens, Wal
1899, May 31	JOHNSTONE, REV. ARCHIBALD -	Inglewood, 9, Pyrland Road, Ri Hill, S.W.
	JONES, JOHN - - -	Holmdale, Clarence Road, Wall
1900, Nov. 28	JONES, J. H. C. - - -	Spa Villa, Canal Street, Cheste
1905, Apr. 26	JONES, R. LEETHAM - -	8, King's Bench Walk, Temple,
1903, May 27	*JUNG, H. E. NAWAB ZUFUR, F.R.A.S.	Hyderabad, Deccan, India.
1892, Nov. 30	KELLY, JAMES - - -	2, Royal Terrace, W., Kingstow Dublin.
	KELLY, O'NEILL F. - - -	Glena Terrace, Wexford, Irelan
	KELLY, W. REDFERN, M.Inst.C.E., F.R.A.S.	Dalriada, Malone Park, Belfast
	KEMPTHORNE, REV. P. H., M.A., F.R.A.S.	Wyok Risington Rectory, Stow Wold.
1905, Feb. 22	KENYON, J. P. - - -	Ingleside, Davenport Crescent, port.
1897, May 26	§§KERNOT, PROF. WILLIAM CHARLES, M.A., C.E.	University, Melbourne, Australi
1898, Dec. 28	KERR, MISS MARY - - -	9, Great Stuart Street, Edinbur
1905, Jan. 25	KERR, PETER - - -	17, Cornwall Street, Edinburgh
	KIDD, B. - - - -	Bramley, Guildford.
1895, Feb. 7	KILLIP, REV. ROBERT, F.R.A.S. -	74, Park Road, Southport.
1899, June 28	KING, ALPHONSO, F.R.A.S. - -	44, Duxbury Road, Leicester.
	‡KIRK, REV. EDWARD BRUCE - -	Manse, Barrhead, near Glasgow
1897, Nov. 24	§§KIRKBY, EDWARD H. - -	Wellington Street, Newmarke toria, Australia.
1897, Apr. 28	KIRKBY, REV. JOHN HENRY - -	Radley College, Abingdon, Berk
1902, Oct. 1	‡KIRKPATRICK, ALEX. B. - -	10, Clairmont Gardens, Glasgo
1901, Dec. 18	KIRMSE, R. - - -	c/o Miss C. G. Smith, Holm Alexandra Road, Malvern.
1898, Dec. 28	KIRWAN, DR. J. ST. L., M.B., M.A. -	District Asylum, Ballinas Galway.
1903, Nov. 25	KITCHING, A. F. - -	18, Hastings Road, Ealing

Date of Election.		
	*KLEIN, SYDNEY T., F.L.S., F.R.A.S. -	Hatherlow, Raglan Road, Reigate, Surrey.
	KLINGLER, EDWARD W. - -	25, Jackson Road, Holloway, N.
, Nov. 28	§KNIBBS, GEORGE H., F.R.A.S. -	Technical College, Harris Street, Ultimo, Sydney, N.S.W.
, Dec. 18	KNIGHT, GEORGE MCKENZIE, F.R.A.S.	10, Agincourt Road, Hampstead, N.W.
Nov. 27	KNIGHTLEY, THOMAS EDWARD, F.R.A.S.	106, Cannon Street, E.C.
	KNOBEL, EDWARD BALL, F.R.A.S. -	32, Tavistock Square, W.C.
Nov. 25	KNOX, GEORGE - - -	Brooklyn House, Semington, Wiltshire.
Mar. 28	*KNOX, LIEUT. HENRY T. C., R.N., F.R.A.S., F.R.G.S.	14, King Street, Portman Square, W.
Dec. 18	KOTZE, R. N., B.A., M.E. - -	P.O. box 550, Johannesburg, South Africa.
Feb. 22	KRUDY, DR. EUGEN VON, M.D. -	Weinbergstrasse, 91, Zurich, Switzerland.
Nov. 29	LAIDLAW, REV. JOHN, B.D. -	United Free Manse, Muthill, Perthshire.
May 25	LAMBERT, CARLTON JOHN, M.A., F.R.A.S., Professor of Mathematics, Royal Naval College, Greenwich.	Omra Lodge, 42, Breakspears Road, Brockley.
June 27	‡LAMBIE, DR. JAMES - -	Kilwinning, R.S.O., Ayrshire, N.B.
Nov. 30	LANCASTER, WILLIAM HENRY -	The White Cottage Epsom.
Oct. 29	LANE, EUSTACE R. - -	George Street, Kettering.
	LASSELL, MISS - - -	Winkton Lodge, Winkton, near Christchurch, Hants.
Oct. 27	§§LAVER, JOHN - - -	Broken Hill Chambers, 375, Flinders Lane, Melbourne, Australia.
Feb. 26	LAWRENCE, JOHN - - -	40, Roker Park Road, Sunderland.
	LEAHY, ARTHUR HERBERT, M.A., F.R.A.S., Professor of Mathematics, Firth College, Sheffield.	92, Ashdell Road, Sheffield.
Feb. 28	LEARMONTH, MISS JUDITH LOUISE -	The Cottage, Northaw, Potter's Bar.
Dec. 18	LE BEAU, OSCAR ALFRED - -	Beaufort House, Commercial Road, Bedford.
	LEDGER, REV. EDMUND, M.A., F.R.A.S.	Protea, Doods Road, Reigate.
Dec. 19	LEES, REV. FREDERICK CLARE, M.A., F.R.G.S.	3, Oaklands Terrace, Swansea.
Dec. 27	LEMOINE, LÉON - - -	36 bis, Boulevard Haussmann, Paris.
Mar. 1	§LENEHAN, HENRY ALFRED, F.R.A.S.	The Observatory, Sydney, N.S.W.
Feb. 20	LENNIE, JOSEPH C. - - -	Rose Park, Trinity Road, Edinburgh.
Mar. 30	LEPPER, GERALD HARPER - -	17, West Street, Maritzburg, Natal.
Nov. 30	LERESCHE, MRS. C. S. - -	8, Ferncroft Avenue, Hampstead, N.W.

Date of Election.		
1896, Dec. 30	*Lebrsche, Miss Flora Macdonald	8, Ferncroft Avenue, Hampst N.W.
	Levander, Frederick William, F.R.A.S., Editor and Librarian.	30, North Villas, Camden Square. N
1901, Mar. 27	Levick, John - - -	Livingstone House, Handsw Birmingham.
1903, Oct. 20	§Lewington, L. H. - - -	c/o Messrs. Dalgetty & Co., Newca N.S.W.
1894, Jan. 31	Lewis, Arthur A. - - -	Ashburnham House, Burry I R.S.O., Carmarthenshire.
	Lewis, Thomas, F.R.A.S. - -	Herbert Villa, Ulundi Road, Bl heath, S.E.
1900, Nov. 28	Libert, L. Lucien - - -	7, Boulevard St. Germain, P
	Lincoln, J. G. - - -	Bank Buildings, 1, High St Croydon.
1900, Dec. 19	Lindsay, John - - -	29, Ludgate Hill, E.C.
1904, Dec. 28	§Lloyd, Mostyn R. - - -	339, Glebe Road, Glebe Point, S ney, N.S.W.
1901, Jan. 30	Loaring, Caroline Edith Florence	Mintaka, Charmouth, Dorset.
1897, Oct. 27	Lobb, Andrew - - -	Mingen Villa, York Avenue, I Cowes, Isle of Wight.
1893, Jan. 25	Loewenthal, Edgar - -	205, Adelaide Road, South Hampst N.W.
	Lohse, Dr. O. - - -	Potsdam, Germany.
	London, William - - -	Woodbridge, Suffolk.
1894, May 30	Long, Charles - - -	Hilldene, 7, Rosslyn Hill, Hampst N.W.
1891, Dec. 30	Long, John S. L., Commander R.N. -	The Firs, Walberton, Arundel, Sus
	Longbottom, Frederick William, F.R.A.S. -	Haslemere, Queen's Park, Chester.
1892, Nov. 30	*Longstaff, George Blundell, M.A., M.D., F.R.C.P.	Highlands, Putney Heath, S.W.
1892, Feb. 24	Loram, Thomas E. - - -	6, East Gate, Exeter.
1898, Apr. 27	§§Love, E. F. J., M.A., F.R.A.S. -	University, Melbourne, Australia.
	*Love, James, F.R.A.S., F.G.S. -	33, Clanricarde Gardens, Baysw W.
1901, Mar. 27	Loxton, Samuel Ernest - -	Fern Dell, Cannock, Stafford.
1894, Nov. 28	Lunt, Joseph, B.Sc., F.I.C., F.R.A.S.	Royal Observatory, Cape of G Hope.
1900, May 30	Lynn, William Thynne, B.A., F.R.A.S.	26, South Vale, Blackheath, S.E.

on.		
12	‡McCallum, James A. - -	194, Ingram Street, Glasgow.
25	McCarthy, Jonadab, F.R.A.S.	11, Colet Gardens, West Ken W.
. 25	McClure, Lady Ellison T. -	Redford House, Colinton, Midl
. 25	McCrum, John Alexander - -	Asylum Square, Inverness.
. 30	MacDonald, Leonard A. -	Box 9, Halcombe, Rangitike Zealand.
24	§Macdonnell, William J. - -	117, Pitt Street, Sydney, N.S.W
	MacEwen, Henry, Director of Mercury and Venus Section.	10, Randolph Place, Mount . Glasgow.
21	McGauran, Edward - -	57, Bignor Street, Hightown chester.
	McGlashan, John - - -	Cawnpore Sugar Works, Ca India.
1	Mackay, W. L., M.A., M.B., Ch.M.	Fairlea, Louisa Road, Snail Sydney, N.S.W.
9	‡Mackenzie, John - -	173, George Street, Glasgow.
. 25	‡Mackintosh, Robert - -	10, Great George Street E Glasgow.
. 30	Maclachlan, Norman - -	Routenburn School, Largs, Sc
20	§McLaughlin, John - -	Yanko, Evans Street, W Sydney, N.S.W.
20	‡Maclay, William - - -	Corn Exchange Buildings, Hop Glasgow.
e 28	McLean, Rev. Malcolm Parker Miller, M.A.	The Rectory, W. Raynham, N
. 26	§Maclellan, Miss Cecilia -	87, Phillip Street, Sydney, N.S
. 31	McLennan, John - -	11, Burn Place, Dingwall, N.B
. 22	Mairet, Charles - -	12, Blythwood Road, Crouch
. 25	Mallett, Charles - -	St. Ronans, Sunny Gardens, N.W.
. 25	Mansergh, Lieut.-Col. Arthur Wentworth.	Manor House, Warrenpoint, c Ireland.
	Markwick, Colonel E. E., C.B., F.R.A.S., Director of Variable Star Section.	Innisfallen, Campbell Road, B Hants.
. 19	Marrian, F. E. - - -	19, Minster Road, West Ha N.W.
	Marshall, George - - -	Inland Revenue, Somerset Strand, W.C.
. 22	Marten, Chas. H. - - -	Conduit Lodge, Blackheatl Blackheath, S.E.
	*Martin, Edward Downes - -	Killoskeham Castle, co. Tippe
v. 29	Martin, Rev. Sydney Ernest -	Malta Villa, Speen, Newbury,
y 25	Maskelyne, Edmund Mervin Booth Story, M.A.	Hatt House, Box, Chippenham
y 25	Maskelyne, J. Nevil, F.R.A.S. -	No address.
ie 27	Maskelyne, Mrs. - - -	No address.
v. 26	§Matthews, Charles - -	Savernake, Gore Hill, N. N.S.W.

Date of Election.		
1893, Jan. 25	MATTHEWS, GEORGE H. - -	68, Bloomfield Street, Derby.
1901, Dec. 18	MATTHEWS, LIEUT. WALTER VIVANTI DEWAR, R.A.	c/o Cox & Co., 16, Charing Cr W.C.
	Maunder, E. Walter, F.R.A.S., Past President, Director of Cometary Section.	86, Tyrwhitt Road, St. John's, S.E.
1891, Nov. 25	MAUNDER, MRS. E. WALTER -	86, Tyrwhitt Road, St. John's, S.E.
1898, Oct. 26	MAUNDER, MISS EDITH - -	86, Tyrwhitt Road, St. John's, S.E.
	MAUNDER, GEORGE WILLIAM -	11, Rostrevor Terrace, Rathgar, Dul
1899, Dec. 27	MAUNDER, MISS IRENE - -	86, Tyrwhitt Road, St. John's, S.E.
	MAUNDER, THOMAS FRID, F.S.A.A. -	136, Rodenhurst Road, Clapham P S.W.
	***Maw, William Henry, F.R.A.S., Past President, Treasurer.**	18, Addison Road, Kensington, W.
	MAXWELL, DR. J. - - -	37, Rue Thiac, Bordeaux, France.
1899, Nov. 29	MAXWELL, RICHARD PONSOBY -	Foreign Office, S.W.
	MAY, CHARLES J. - - -	Castle Street, Woodbridge, Suffolk.
1894, Feb. 28	MAY, PHILIP - -	1, Hilldrop Crescent, Camden Road,
1896, Dec. 30	MAYNARD, HARRY RUSSELL - - -	Toynbee Hall, 28, Commercial Str Whitechapel, E.
	MEARES, JOHN WILLOUGHBY, F.R.A.S., M.I.E.E.	58, Chowringhee, Calcutta.
	MEE, ARTHUR B. P. - -	Tremynfa, Llanishen, Cardiff.
1898, Mar. 30	MEERS, A. W., F.R.G.S. - -	Lugano, 48, Wickham Rd., Beckenh
1898, Apr. 27	§§MEIKLEJOHN, REV. JOHN, D.D. -	Dorcas Street W., South Melbou Australia.
1893, Nov. 29	*MELVILL, EDWARD HARKER VINCENT.	Government Surveyor, P. O. Box, Johannesburg.
	*§§MELVIN, JOHN - - -	101, Elizabeth Street, Melbou Australia.
1895, Nov. 27	MENDHAM, MISS GERTRUDE A. -	Shepscombe House, near Str Gloucestershire.
1894, Nov. 28	§MERFIELD, CHARLES J., F.R.A.S. -	Railway Construction Departm Public Works, Sydney, N.S.W.
1893, May 31	MERLIN, A. A. C. ELIOT - -	Volo, Greece.
1891, Nov. 25	MILLER, GORDON W. - - -	Bathurst Lodge, Blackheath, S.E.
1899, May 4	§§MILLER, JAMES - - -	10, St. Vincent Place, S., Albert P Melbourne, Australia.
1895, Mar. 27	MILLES, C. W. - - -	St. James' Chambers, 2, Ryder St St. James', S.W.
1894, Dec. 19	MILNE, WILLIAM - -	Union Bank of Scotland, Lim Tarland, Aberdeenshire.
1903, Nov. 25	MISKIN, ALBERT FRANCIS, L.R.C.P., M.R.C.S.	12, The Parade, Plaistow Road, Ham, E.
1901, Dec. 18	MITCHELL, ARTHUR EDWARD -	9, Lr. Mt. Pleasant Avenue, Rathm Dublin.
	MITCHELL, REV. JOHN CAIRNS, B.D., F.R.A.S.	Rutland Cottage, Parkgate Chester.
1893, Dec. 27	MIZZI, LEWIS FRANCIS, LL.D. -	Constantinople.

Date Election.		
, Mar. 30	Molera, E. J. - - -	2025, Sacramento Street, San Francisco, Cal., U.S.A.
, Mar. 29	Molesworth, Sir Guilford L., K.C.I.E.	The Manor House, Bexley, Kent.
	*Molesworth, Major P. B., R.E., F.R.A.S.	Trincomalee, Ceylon.
, Nov. 28	Molyneux, Thomas - -	Earlestown, Lancashire.
	*Monck, William Henry Stanley, M.A., F.R.A.S.	16, Earlesfort Terrace, Dublin.
, Apr. 18	§Mooney, L. - - - - -	92, Oxford Street, Sydney, N.S.W.
, May 31	Moore, Alfred George - -	Osborne, Humberstone Drive, Leicester.
, Nov. 24	Moore, H. Keatley, B.A., B.Mus. -	Chipstead, Chepstow Rise, Eas Croydon.
, June 27	Moore, T. J. - - -	Field House, Hatfield, near Doncaster.
, Apr. 26	Moran, Joseph P. - -	The National Bank (Limited), Pembroke Branch, Baggot Street Bridge Dublin.
, Apr. 29	Moreux, l'Abbé Th. - -	Observatoire, Bourges (Cher), France
, Mar. 28	Morford, Rev. Augustin - -	The Friary, Saltash, Cornwall.
, Nov. 25	Morgan, Miss E. A. - -	20, Loudoun Road, St. John's Wood N.W.
, Nov. 30	Morozow, Prof. Paul - -	Gymnasium of Yaroslav, Russia.
, Mar. 1	§Morris, E. Reginald - -	Seaview Street, Marrickville, Sydney N.S.W.
, Nov. 30	Morris, Percy, F.R.A.S. - -	Holmwood, Camborne Road, Sutton Surrey.
	Morris, P. A. - - -	Rosebank, Harrow View, Harrow.
	Moser, Miss Edith E. - - -	Carbery, Christchurch, Hants.
, Dec. 29	Moye, Marcel, D. en D., Professeur à la Faculté de Droit.	3, rue Achille-Bégé, Montpellie (Hérault), France.
, Dec. 28	Muirhead, George - -	30, Charlotte Square, Edinburgh.
, Nov. 28	Muller, A. M. du Cellioe -	Nÿmegen, Holland.
, Feb. 20	Munro, John Edward, Junr. -	Oak Lawn, Bromley Road, Beckenham
, Dec. 29	Murdoch, George H. - -	31, Nassington Road, Hampstead, N.W
, Nov. 28	§Murphy, The Most Revd. Daniel, Archbishop of Hobart.	Tasmania.
, Feb. 25	Naegamvala, Kavasjee D., M.A., F.R.A.S.	Maharajah Takhtasingji Observato Poona, India.
	Nash, Frederick William, F.R.A.S.	The Firs, Bentley Heath, Kn Warwickshire.
Dec. 19	Nash, William - - -	The Grammar School, Swaffha folk.

Date of Election.		
1895, Feb. 27	NEATE, ALFRED NOEL, C.E., F.R.A.S.	49, Fulwood Road, Aigburth, pool.
1898, Dec. 16	‡NEILSON, JAMES - - -	116, Bishop Street, Port D Glasgow.
1892, Dec. 28	*NELSON, EDWARD MILLES - -	Beckington, Bath.
	NELSON, REGINALD CARTER, F.R.A.S. -	19, Roker Terrace, Sunderland.
1891, Mar. 25	*NELSON, W. F. J. - - -	Salisbury Green, Edinburgh.
1898, Oct. 26	*NEWALL, HUGH FRANK, M.A., F.R.S., F.R.A.S.	Madingley Rise, Cambridge.
	NEWBEGIN, GEORGE JAMES, F.R.A.S. -	Lyndale, Langley Park Road, S Surrey.
1905, June 28	NEWBOLD, WILLIAM, M.A., F.R.A.S.	7, Broadwater Down, Tun Wells.
1902, Dec. 31	NICHOLLS, CAPT. A. E., F.R.A.S. -	Cotswold, Ernest Road, Hornc Essex.
1898, Nov. 30	NICHOLSON, DANIEL, F.R.G.S., F.Z.S.	Rocklands, St. Lawrence, Is Wight.
1898, Nov. 30	NICHOLSON, JOSEPH SINCLAIR -	Rocklands, St. Lawrence, Is Wight.
1899, Dec. 16	NICOLSON, ANDREW, S.S.C. -	1, Hatton Place, Edinburgh.
1891, May 27	NICOLSON, WILLIAM - - - -	Stella House, Exeter Road, Exe Devon.
	NIELD, H. KRAUSS, F.R.A.S. - -	20, New Bridge Street, E.C.
	NIELSEN, VICTOR - - -	Private Observatory, Villa U Copenhagen, F.
1899, Feb. 22	NORMAN, REV. PHILIP - -	The Manse, Scone, N.S.W.
1903, Apr. 29	NÖRREGAARD, REV. ARTHUR HENRY, M.A.	5, Cyprus Road, Church Finchley, N.
1903, Nov. 25	NORREYS, MRS. ATHERTON JEPHSON	The Castle, Mallow, co. Cork, Ir
1899, Dec. 27	NORRIE, WILLIAM - - -	Cairnhill, Turriff, Aberdeenshire
1896, June 16	§NORTHROP, J. H. - - -	Glassop Street, Balmain, S N.S.W.
1896, Nov. 25	OAKES, WALTER - - -	57, West Beech Road, Noel Wood Green, N.
1897, Mar. 31	OBSERVATORY OF THE IMPERIAL UNIVERSITY OF ST. PETERSBURG.	St. Petersburg, Russia.
1905, Mar. 29	OBSERVATORY OF THE UNIVERSITY OF UPSALA.	Upsala, Sweden.
1900, Apr. 25	O'CALLAGHAN, I. - -	Baronsmead, Farnborough.
1903, Feb. 25	O'CONNELL, REV. F. W. - -	Newtownforbes, co. Longford, I
1905, May 31	O'FERRALL, MRS. SARAH LONGSDON	The Chestnuts, Little Bowden, Harborough.
1891, Feb. 25	OFFORD, JOHN MILTON, F.R.M.S. -	62, Gordon Road, Ealing, W.
	OKELL, SAMUEL, F.R.A.S. - -	Overley, Langham Road, B Cheshire.

Date Election.		
, Apr. 28	§§OLIVER, CALDER EDKINS - -	Rialto, Collins Street, M Australia.
, Feb. 24	OLIVER, JAMES - - -	West Jesmond Villa, New Tyne.
, Oct. 20	§O'NEILL, T. M. - - -	Australian Joint Stock Ban castle, N.S W.
, Nov. 12	‡ORR, JOHN - - - -	64, Craigmaddie Terrace, Sa Street, W. Glasgow.
, Nov. 25	ORR, MISS KATHLEEN ALICE - -	10, Burlington Place, Eastbo
, Oct. 28	*ORR, MISS M. A. - - -	9, Broadway Buildings, Stati Reading.
, May 30	OTTO, LOUIS F. - - -	Diocesan Boys' School, Na India.
, Dec. 16	*‡OVERTOUN, THE RT. HON. LORD -	Overtoun, Dumbarton.
, Nov. 30	OWEN, REV. A. E. BRISCO, M.A. -	Cholderton Rectory, Salisbur
, June 28	OWEN, ROBERT - - -	Kidderminster House, Ffynne nr. Mostyn, North Wales.
, Nov. 30	PACKER, DAVID E. - - -	71, Oak Tree Lane, Selly O Birmingham.
, Apr. 29	PAGE, MISS E. I. - - -	Turret House, Felpham, nea Sussex.
, Nov. 29	PAIN, REV. HAROLD, B.A. - -	St. Matthew's Clergy House Street, Cambridge.
, Dec. 30	PARFITT, EDWARD WILLIAM - -	7, Gatcombe Road, Merce Holloway, N.
, Dec. 27	*PARKER, REV. JAMES DUNNE, LL.D., F.R.Met.S., F.R.A.S.	Bennington House, Stevenage
, Mar. 25	*PARKER, JAMES DUNNE METCALFE -	Bennington House, Stevenage
, Nov. 12	‡PARKINSON, JOHN - - -	Kyleswell Street, Kilwinning,
, Oct. 26	PARKINSON, MISS MARIAN - -	36, Gower Street, W.C.
, Oct. 29	PARLETT, J. M. - - -	c/o A. Scott & Co., Rangoon,
, Oct. 25	PARR, W. ALFRED - - -	34, Viale Principe Amedeo, Italy.
, Jan. 26	PARRY, ROBERT - - - -	Westcote, Hoole, Chester.
, Feb. 27	PARSONS, FREDERICK THOMAS -	27, Southdean Gardens, Southf
, Dec. 30	PARSONS, HAROLD EDWARD STEWART	35, Ludgate Hill, E.C.
, Dec. 30	PARSONS, NORMAN ERNEST - -	35, Ludgate Hill, E.C.
, Nov. 25	PATEMAN, HERBERT - -	11, Willow Brook Road, Leic
, Feb. 28	PATERSON, A. GORDON, M.A., M.D., C.M.	South Lodge, Ascot, Berks.
, Mar. 31	PATXOT, JUBERT RAFAEL, F.R.A.S. -	Passeig, Bonanova 64, Barcelona, Spain.
, Dec. 19	PEARCE, ALFRED JOHN - -	20, Foulser Road, S.W.

Date of Election.		
1898, Nov. 25	‡PEARCE, C. W. BEEAM - -	189, West Regent Street, Glasgo
1897, Apr. 28	§§PEARCE, THOMAS - - -	St. James Park, Hawthorne, Vi Australia.
1892, Apr. 12	PEARSON, T. ARTHUR - -	Rock Bank, Milnrow, near Roch
1896, Nov. 25	PECK, WILLIAM, F.R.S.E., F.R.A.S. -	The Observatory, Calton Hill, burgh.
	PECKHAM, REV. ARTHUR M. -	10, The Limes Avenue, New S gate, N.
	PENNINGTON, COLONEL W. A. - -	Lake House, Netley Abbey, S ampton.
1900, Nov. 28	PERCIVAL, REV. STANLEY EDWARD, M.A.	Vicar of Merriott, Somerset.
1892, Dec. 28	PEREIRA, JOAO DE MORAES, Professor at the National Lyceum.	Ponta delgada, S. Miguel, Azores
1899, June 28	PERIDIER, JULIEN - - -	20, Rue du Regard, Paris VI.
	PERRY, ARTHUR C. - -	226, Halsey Street, Brooklyn, York, U.S.A.
	Petrie, James George, F.R.A.S., Secretary.	359, Holloway Road, N.
1900, Nov. 28	PHILLIMORE, REV. ARTHUR -	Brightwell-Baldwin, Wallingford.
	PHILLIPS, JOHN - - -	Thornleigh, 34, Ryelands S Hereford.
1900, Dec. 5	PHILLIPS, REV. J. B., M.A. - -	Falinge Vicarage, Rochdale.
1896, Nov. 25	**Phillips, Rev. Theodore E. R., M.A., F.R.A.S., Director of the Jupiter Section.**	50, Alexandra Road, Addisc Croydon.
1894, Jan. 31	*PICKERING, PROF. E. C., D.Sc., A.R.A.S.	Harvard Observatory, Camb Mass., U.S.A.
1901, June 26	PIKE, JAMES ROBERT - -	5, Trinity Road, Tulse Hill, S.W
	*PIKE, R. W. - - -	Yerkes Observatory, Williams Wis., U.S.A.
1898, Apr. 27	PILCHER, H. D. - - -	21, Ennismore Gardens, S.W.
1892, Jan. 27	PIM, ALAN WILLIAM, C.S. - -	Mahoba, District Hamirpur, Western Provinces, India.
	PIM, FREDERIC W. - -	Lonsdale, Avoca Avenue, Blac co. Dublin.
	PLASSMANN, J. - - -	Nordstrasse, 19, Münster, West Germany.
1897, Dec. 29	PLEDGE, JOHN H. - - -	115, Richmond Road, N.E.
1901, Dec. 18	PLUMMER, LIEUT. THOMAS HERMAN, R.A.	Auberge de Castille, Malta.
	PLUMMER, WILLIAM EDWARD, M.A., F.R.A.S.	Liverpool Observatory, Birkenhe
1891, Dec. 30	POLLOCK, GEORGE FREDERICK -	Hanworth, Middlesex.
1895, June 27	§POLLOCK, J. ARTHUR, B.E., B.Sc. -	The University, Sydney, N.S.W
	POLSON, THOMAS R. J., M.R.I.A. -	13, Wellington Place, Enniskille
1891, Mar. 25	POPE, JAMES T. - - -	1, Crawford Street, Dingwall, N.
1891, May 27	PORRO, PROF. FRANCESCO, Professor of Astronomy.	The Royal University, Genoa, I
1897, Feb. 20	PORTER, JOHN S. - - -	57, Fountainbridge, Edinburgh.
1891. Oct. 28	PORTSMOUTH, THE DOWAGER COUNTESS OF.	Townsend, Over Wallop, Stoc Hampshire.

te ction.		
	POTTER, HERBERT - -	145, Richmond Road, Hackney, N.E.
	POWELL, SEPTIMUS - - -	The Hermitage, Weston-super-Mare.
	*POWER, J. - - -	Royal Observatory, Cape of Good Hope.
ov. 30	POWLES, CHARLES PLUMMER -	Wellington, New Zealand.
ay 26	§§PRESTON, CHARLES PAYNE -	Church Street, Abbotsford, near Melbourne, Australia.
ec. 4	PRICE, JOHN BENNETT - -	Wyresdale, Chorlton-cum-Hardy, near Manchester.
	PRICE, W. S. - - - -	Fernleigh, Wellington, Somerset.
lar. 28	PRIOR, S. J. BURRELL - -	Trelyon, 232, South Norwood Hill, S.E.
	PROCTOR, JOHN THOMAS - -	Sleaford Villa, Oadby Road, Wigston, near Leicester.
une 30	PROCTOR, MISS MARY - -	1,311, 14th Street, Washington, D.C.
lay 31	PROCTOR-SMYTH, MRS. -	Eversley, Manchester Road, Altrincham.
ec. 18	PULLIN, JAMES HENRY - -	7, Amhurst Park, Stamford Hill, N.
an. 28	PUNCH, J. W. R. - - -	Hastoe House, Southfield Road, Middlesborough.
une 27	PURCELL, COL. M. H., R.E. -	50, Tedworth Gardens, Chelsea, S.W.
ec. 19	§QUAIFE, FREDERICK HARRISON, M.A., M.D.	Hughenden, Woollahra, Sydney, N.S.W.
ct. 31	QUILTER, REV. FREDERICK WILLIAM, D.D.	The Rectory, Waddington, Lincoln.
an. 31	RABONE, ERNEST - -	85, Avenue Road, Highgate, N.
	RADMORE, THOMAS - -	Durlstone, 3, Cavendish Road, Southsea.
eb. 8	‡RAE, ROBERT - - -	91, Bothwell Street, Glasgow.
Mar. 28	RAISIN, CAPT. FRANK WILLIAM, R.N.R.	184, Venner Road, Sydenham, S.E.
ec. 18	RAISIN, HAROLD WOODGATE -	41, Heath Hurst Road, Hampstead, N.W.
	RALPH, WILLIAM G. - - -	26, Colebrooke Avenue, West Ea
ct. 25	RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.S., F.R.A.S., Radcliffe Observer.	Radcliffe Observatory, Oxford.

Date of Election.		
1901, Jan. 30	Raymond, Frederick Lancelot -	Wayside, Yeovil, Somerset.
1894, Mar. 28	Read, R. W. - - -	258, Crystal Palace Road, Dul S.E.
1892, Nov. 30	Redmayne, Robert Robey, B.A., LL.B.	Chetwynd Place, Lichfield.
1897, Apr. 20	§Rees, Evan - - -	Stockton, N.S.W.
1904, Nov. 30	Reichwein, Alfred - - -	Schloss Strasse, 123, Steglitz, Berlin.
	Reid, Rev. Vincent - -	St. Mungo's Academy, Townh Glasgow.
	Relton, Harry - - -	Underfell, Saltwell, near Gateshea
1895, Dec. 18	*Rendell, Robert Fermor, B.A., F.R.A.S.	Natal Observatory, Durban, S Africa.
1900, Oct. 31	Reynolds, John H., F.R.A.S. -	Malvern House, Trinity Road, Bi field, near Birmingham.
	Reynolds, William John, F.R.A.S. -	Varna, Fox Lane, Palmer's Green
1897, Feb. 20	Rheden, Joseph - - -	K.K. Sternwarte, Vienna, XVIII.
1894, Oct. 31	Rice, John, R.N. - - -	Elmcroft, Silverdale, Sydenham, S.
	Richardson, Lawrence - -	Stoneham, Beech Grove Road, N castle-on-Tyne.
1899, Feb. 22	Ripley, Henry E. - - -	Ashley Manor, Cheltenham.
1903, Oct. 28	Rix, Miss Edith Mary - -	The Bank, Beccles.
	Roberts, Alexander William, D.Sc., F.R.S.E., F.R.A.S.	Lovedale, South Africa.
1899, Jan. 25	Roberts, Rev. Ellis Gregory, M.A.	The Rectory, Newbold-on-St Stratford-on-Avon.
1896, June 24	Roberts, Mrs. Isaac, D.-ès-Sc. -	Chateau Rosa Bonheur, By Thom Seine-et-Marne, France.
1899, Nov. 29	Roberts, Richard Frind, A.C.A. -	Westcroft, Westhall Road, W lingham, Surrey.
	Robertson, John - - -	35, Causewayend, Coupar Angus,
1899, Feb. 17	*‡Robertson, Robert, B.Sc., C.E. -	154, West George Street, Glasgow
1896, June 24	Robinson, William Henry, F.R.A.S.	Offendene, Walsall.
1894, Jan. 31	Robinson, W. S., M.A. - -	Courtfield, Westhill, Putney Heat
1895, Jan. 9	Rogers, Henry Montague -	Iona, West Hill, Hastings.
1892, Oct. 26	*Rogers, T. A., F.R.C.S. - -	23, Endsleigh Street, W.C.
	Roods, Alfred - - -	67, Thornhill Road, Croydon.
	Roome, Rev. W. J. Boden, F.R.A.S.	13, Cumberland Road, Acton, W.
	*Rose, C. M. - - -	Highfield, Harmer Green, Wel Herts.
1895, Mar. 1	§Roseby, Rev. Thomas, M.A., LL.D., F.R.A.S.	Marrickville, Sydney, N.S.W.
1905, Mar. 16	‡Ross, Alexander D. - -	7, Queen's Terrace, Glasgow, W.
1897, Apr. 28	§§Ross, David - - -	National Bank, Melbourne, Austr
	Rosse, The Rt. Hon. the Earl of, K.P., B.A., LL.D., D.C.L., F.R.S., F.R.A.S.	Birr Castle, Parsonstown, Ireland.
1893, Nov. 29	Row, Mrs. Elizabeth North -	Cove House, Tiverton, N. Devon.
1900, Apr. 25	Rowan, Andrew - -	37, Osborne Terrace, Clapham S.W.
1893, Apr. 11	Rowbotham, W. H. - -	Holyrood Place, Newton Manchester.

Date Election.		
Apr. 27	Russell, Frederick William, M.A.	Dulwich College, S.E.
Mar. 1	§Russell, Henry Chamberlaine, B.A., F.R.S., F.R.A.S., Director, Sydney Observatory.	Sydney, N.S.W.
Jan. 19	‡Russell, The Very Rev. James C., D.D.	9, Coates Gardens, Edinburgh.
Oct. 30	Russell, Samuel Marcus, M.A., F.R.A.S.	Deputy Commissioner, Imperial time Customs, Canton, China.
	Ryle, Reginald John, M.A., M.B., M.R.C.S.	15, German Place, Brighton.
May 31	Ryves, Percy M. - - -	The Westbrook Memorial, H Hounslow.
Nov. 29	Salmon, Richard George - -	41, Preston Road, Westcliff-o Essex.
June 28	Salmon, S. H. R. - - -	Chaseleigh, Birdhurst Road, Cro
Mar. 29	Sampson, Prof. Ralph Allen, M.A., F.R.A.S.	Observatory House, Durham.
Feb. 26	Sandeman, William, F.C.A. -	Hollin Bank, Oswaldwistle, Accrington.
Apr. 27	Sandford, Miss Alice - -	33, Hertford Street, Mayfair, W.
Feb. 25	*Sargant, Wm. L., B.A. - -	School House, Oakham.
	***Saunder, Samuel Arthur, M.A., F.R.A.S., Past President.**	Fir Holt, Crowthorne, Berks.
May 30	Sauvée, Albert - - -	60, Park Street, Southwark, S.E.
	Sawyer, Robert - - -	10, Craig's Court, Charing Cross,
May 26	§§Schäfer, Richard - -	212, Swanston Street. Melb Australia.
May 29	Schindler, Dr. Joas Henrique -	102, Rua S. Francisco da Lisbon.
	Schooling, William, F.R.A.S. -	25, Westminster Palace Ga Artillery Row, S.W.
	Schooling, Mrs. - -	25, Westminster Palace Ga Artillery Row, S.W.
	Schram, Dr. Robert - -	Staudgasse, 1, Vienna, XVIII.
Mar. 29	Scott, Mrs. Gertrude E. -	2, Hendon Lane, Church End, ley, N.
	Scott, James Lidderdale, F.R.A.S. -	c/o Scott, Harding, & Co., Sh China.
May 31	Scott, Miss Marjory - -	St. Peter's Grove, York.
	Seabroke, George Mitchell, F.R.A.S., Past President, Director of Saturn and Double Star Sections.	Rosemont, Rugby.
May 25	§§Searle, James - - -	23, Union Lane, Melbourn
May 28	Sears, Joseph - - -	8, Buckingham Road, Ne Sussex.

Date of Election.		
1892 May 25	See, T. J. J., A.M., Ph.D., F.R.A.S. -	The Observatory, Mare Islan fornia, U.S.A.
1900, May 30	Sewell, Ebenezer James - -	84, Arundel Gardens, Notting H and Highlands, Maldon, Es
1904, Apr. 27	Shackleton, William, F.R.A.S. -	Royal College of Science, Sout sington.
1896, Mar. 25	Sharman, Nathaniel Pearce -	Swanspool House, Wellingboro
	Sharman, Mrs. - - - - -	Swanspool House, Wellingboro
	Sharp, Martin Charles, M.A., F.R.A.S.	2, Ingleside Grove, Westcomb Blackheath, S.E.
1898, Nov. 30	*Sharpe, Rev. A. B., M.A. -	Upper Heyford Rectory, Banb
1905, May 31	Shaw, Rev. Francis Longsdon, M.A.	The Chestnuts, Little Bowden, Harborough.
	Shearmen, T. S. H. - - -	2,168,Fifth Avenue, Vancouver, Columbia, Canada.
	Sheldon, Thomas Steele, M.B., F.R.A.S.	Parkside, Macclesfield.
1892 Nov. 30	*Shervill, Frank, M.A. - -	New College, Cliftonville, Mar
	Sherwen, John - - -	The Grange, Egremont, viâ Ca
1904, Feb. 24	Shields, Frederic W., M.A. -	Wylam-on Tyne.
	Sidgreaves, Rev. Walter, S.J., F.R.A.S.	St. Mary's Hall, Stonyhurst, Bla
1897, Jan. 27	Simas, Lieut. Manuel Soares de Mello e.	Trafaria, viâ Lisbon.
1896, June 24	Simpkins, W., J.P. - - -	Henley-on-Thames.
1898, Apr. 27	Simpson, David Goudie, F.R.A.S. -	Rosefield, Widmore Road, B Kent.
1896, Nov. 25	Simpson, Thomas - - -	Fennymere, Castle Bar, Ealing
	Slade, Rev. H. P. - - -	11, Westcott Street, Hull.
1905, Mar. 21	§Slade, W. Hermon - - -	Sussex Street, Sydney, N.S.W.
1897, Apr. 28	§§Smale, George - - -	Glenroy, Victoria, Australia.
	Smart, David, M.R.C.S., L.R.C.P., F.R.A.S.	108, Grange Road, S.E.
1899, Oct. 5	§§Smart, Francis Joseph -	11, Elizabeth Street, Melbourn tralia.
1895, Jan. 9	Smith, Alexander - -	Union Bank of Scotland, Ltd., N.B.
1891, Oct. 28	Smith, Alfred Oxnard - -	28, Old Elvet, Durham.
1897, Feb. 20	Smith, Charles F. O. - -	108, Findhorn Place, Edinburg
1898, Nov. 30	*Smith, Charles Michie, B.Sc., F.R.S.E., F.R.A.S., Government Astronomer.	Kodaikânal, Palani Hills, Scut
1897, Nov. 24	Smith, Francis Lys - - -	3, Grecian Cottages, Crow Norwood, S.E.
1895, Feb. 27	Smith, Harold F. - - -	25, Brook Street. Luton, I shire.
1894, Dec. 19	§Smith, James - - -	The Saw Mills, Jilliby Jilliby,
1896, May 19	§Smith, J. McGarvie - -	Denison Street, Woollahra, N.S.W.
1898, May 25	Smith, John Peter George, F.R.A.S.	Sweyney Cliff, Coalport, R.S.O shire.

Date Election.		
Mar. 25	SMITH, CAPTAIN JOHN WILLIAM -	Weyhill, near Andover, *Hants.*
May 29	SMITH, T. J. FORRESTER - -	Newstead, Wavertree, *Liverpool.*
Dec. 27	*SMITH, WILLIAM - - -	Municipal Technical Schools, Birmingham.
Mar. 27	SMITH, WILLIAM ARTHUR, F.R.A.S. -	154, Hagley Road, Edgbaston, Birmingham.
Apr. 27	SMITH, W. E., C.B. - - -	10, Hillbury Road, Tooting Common, S.W.
Dec. 27	SMITHERS, HENRY WILLIAM - -	Ashurst Place, Langton Green, Tunbridge Wells.
	SOMERVILLE, J. W. - -	Merlefield, Helensburgh.
June 17	§SOUTER, ALEXANDER J. -	Commercial Bank, Sydney, N.S.W.
Feb. 26	SPARKES, WILLIAM EDWARD, F.R.A.S.	8, Claremont Terrace, Sunderland.
Dec. 18	*SPRINGALL, DONALD R., M.P.S. -	St. Andrew's House, St. Andrew's Street, Norwich.
Mar. 30	STACPOOLE, MISS FLORENCE -	82, Porchester Terrace, Hyde Park, W.
	STAFFORD, Z. W. - -	Waldeck House, Enfield.
May 27 Oct. 31	STAHN, JUSTICE, Secretary, Astronomical Section, Maryland Academy of Sciences.	506, Ensor Street, Baltimore, U.S.A.
	STANLEY, WILLIAM FORD, J.P., F.R.A.S., F.G.S., F.R.Met.S.	Cumberlow, South Norwood, S.E.
	STANTON, WALTER J. -	Stratford Lodge, Stroud, Gloucestershire.
, May 27	STAUS, DR. ANTON - - -	Kornblumenstrasse, 2, Carlsruhe, Baden.
	STELLING, WALTER - - -	Villa Solheim, Vedbæk, Denmark.
, May 27	STEVENS, MISS CATHARINE O. -	The Red House, Bradfield, Reading.
, May 30	STEVENSON, ARTHUR HOWE -	102, Riggindale Road, Streatham, S.W.
, Dec. 1	STEVENSON, ISAAC - -	Laurel House, Burrowa, N.S.W.
	*STEWARD, JOHN J., F.R.A.S. -	63, Leyland Road, Lee, S.E.
, Nov. 12	‡STEWART, HENRY JOHN - -	18, Montgomerie Quadrant, Kelvinside, Glasgow.
	STEWART, REV. WALTER EDWARD, M.A., F.R.A.S.	Longney Vicarage, Gloucester.
, Dec. 29	STIKLOW, C. H. W. - - -	78, Thorny Hedge Road, Gunnersbury, W.
, Nov. 12	‡STIRLING-MAXWELL, SIR JOHN M., BART M.P	Pollok House, Pollokshaws, Glasgow.
, Apr. 30	STONES, FRANCIS DAVID - -	1, Wellington Villas, Crewe, Cheshire.
, Oct. 28	*STONEY MISS EDITH ANNE - -	30, Ledbury Road, Bayswater, W.
, Oct. 28	STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., F.R.A.S.	30, Ledbury Road, Bayswater, W.
, Nov. 24	STRAKER, DONALD - - -	Haslemere, Surrey.
, Apr. 27	STRAFFORD, THE DOWAGER COUNTESS OF.	13, Lower Berkeley Street, Portman Square, W.
, Mar. 29	STREET, GEORGE, M.A. - -	Merton House, Southwick.
Oct. 1	STROMEYER, C. E. - - -	Lancefield, Didsbury, near Manchester.
Nov. 25	STUART, EDWARD OGILVY - -	6, Eastcombe Avenue, Charlton.
May 27	STUART, SAMUEL - -	View Road, Auckland, N.Z.

Date of Election.		
1893, Oct. 25	Sturgeon, Wentworth - -	4, King's Bench Walk, E.C.
1895, Nov. 27	Stutter, Rev. Edward John, O.S.B., F.R.A.S.	Acton Burnell, Shrewsbury.
1901, May 29	Suart, Arthur B. - - -	Walden, Burnham, Bucks.
1893, Oct. 25	Sugg, Henry - - -	c/o J. W. Sugg, Dorking, Surrey.
	Sugg, John Walter, F.G.S. - -	Knollbrow, Dorking.
1904, Dec. 28	Sullivan, Arthur - - -	Orchardton, Dundrum, Co. Dubli
1897, Nov. 24	Swasey, Ambrose, F.R.A.S. -	Cleveland, Ohio, U.S.A.
	Swift, Lewis, F.R.A.S. - -	Marathon, Cortland County, York, U.S.A.
1893, Feb. 14	Sykes, Herbert Rushton - -	Lydham Manor, Bishop's C Shropshire.
1894, Nov. 12	‡Sykes, William - - -	24, Hamilton Park Terrace, Hill-l Glasgow.
1902, Nov. 20	§Sykes, William Morton -	Croydon Road, Croydon, Syd N.S.W.
1899, Mar. 29	Tabor, Charles James - -	The White House, Knotts Gr Leyton.
1897, Dec. 29	Tappenden, Laurence Barnard -	Wickham Lodge, 20, Cumberland R Kew Gardens.
1901, Mar. 27	Tatham, Miss C. M. - - -	36, Gower Street, W.C.
1903, Nov. 25	Tatham, Guy Thomas Percy	St. Andrew's Lodge, Watford.
1896, Mar. 25	Taylor, William - - -	50, Manor Park, Lee, S.E.
1905, Apr. 26	Tchistosserdoff, M. - -	12, Ambavnaya, St. Petersburg.
1891, June 24	§Tebbutt, John, F.R.A.S. - -	Observatory, Windsor, New S Wales.
	Tennant, Lt.-Gen. James F., C.I.E., R.E., F.R.S., F.R.A.S.	11, Clifton Gardens, Maida Hill, W
1892, Jan. 27	Terby, François, D.Sc., F.R.A.S. -	96, Rue des Bogards, Louvain, Belg
1898, Dec. 28	Tetley, William Charles - -	Hillside Cottage, Aspley Guise, R.S Bedfordshire.
1892, Dec. 28	Tetley, William Nichols - -	Portora, Enniskillen.
1899 June 28	Thirlby, Arthur H. - - -	Measham, Atherstone.
1896, Mar. 1	§Thomas, William M. - -	District Survey Office, Dubbo, N.S
1897, Feb. 24	Thompson, George Carslake, LL.M.	Park Road, Penarth, Cardiff.
1905, Jan. 25	Thomson, Harold - - -	6, St. Bede's Park, Sunderland.
1899, Dec. 15	‡Thomson, John, I.A. - -	Ingleneuk, Monreith Road, Lang Glasgow.
1905, Apr. 26	Thornley, John Hardwick, M.B. -	1, Carlton Terrace, Scarborough.
1900, Oct. 31	Thorold, Miss Ellinor - -	Warkleigh House, Umberl R.S.O., North Devon.
1892, Nov. 8	Thorp, Thomas, F.R.A.S. - -	Moss Bank, Whitefield, near M chester.
	Thorp, Rev. W. Paxton - - -	Little Yeldham Rectory, Hals Essex.
	Thwaites, Christopher, M.Inst.C.E., F.R.A.S.	Burnell Road, Sutton, Surrey.

ate ection.		
May 28	TIFFIN, LEONARD GEORGE HENRY -	20, Lyme Street, Camden R
Nov. 25	TODD, JOHN M. R. - - -	Hextable Lodge, Swanley, K
May 31	TOMKINS, H. G. - -	Lahore, Punjab, India.
Dec. 18	*TONQUIST, MARTIN - -	Calle Bartolomé Mitre, 53 Aires, Argentine Republi
Dec. 28	TREMILLS, REV. RALPH VINCENT, B.A., A.K.C.	62, Margravine Gardens, W sington, W.
	§§TUCKER, REV. CANON H. -	Christ Church, South Yarra, Australia.
Nov. 25	TUCKFIELD, REV. J. H. - -	Parsonage, Church Street, Melbourne, Victoria, Aus
Nov. 12	‡TULLOCH, MALCOLM - -	21, Clifford Street, Ibrox, G
Jan. 25	TURNBULL, JOSEPH - - -	Laurel House, North Hill, Hi
	*TURNER, HERBERT HALL, M.A., D.Sc., F.R.S., F.R.A.S., Savilian Professor of Astronomy.	University Observatory, T Oxford.
Feb. 20	TURNER, JOHN, M.A., B.Sc. - -	47, Mayfield Road, Edinburg
Jan. 29	UPTON, CHARLES -	Tower House, Stroud, Glouc
Dec. 19	URQUHART, WILLIAM -	107, Portsdown Road, Maid
Dec. 29	VALLACK, EDMUND -	39, Kildare Terrace, Bayswa
Nov. 27	VERDE, CAPT. FELIX - -	Spezia, Via Fasio, 2, Italy.
Apr. 24	VEZEY, JOHN JEWELL, F.R.M.S. -	188, Lewisham High Road, S.E.
Feb. 22	VICKARS-GASKELL, REV. GEORGE, F.R.A.S.	Grange-over-Sands.
Nov. 25	VIGNOLES, E. B. - - - -	27, Ridgmount Gardens, W.
Oct. 28	VIZARD, PHILIP EDWARD, F.R.A.S. -	Belsize Lodge, Belsize Lan stead.

Date of Election.		
1895, Jan. 9	‡WADDELL, JAMES, C.E. - -	15, Moray Place, Glasgow.
1896, May 27	WADMORE, JOHN MELLO - -	Aldenham School, near Elstree, I
1896, Nov. 25	WADSWORTH, REV. HENRY, F.R.M.S.	The Grange, Wadsley Bridge, She
	*WAKE, CHARLES - -	120, Broadway, New York, U.S.A
1891, May 27	WAKE, HENRY - - -	90, Scotch Street, Whitehaven.
	*WALKER, ARTHUR JOHN, M.A., F.R.A.S.	Mount St. John, Thirsk, Yorkshir
1904, Nov. 15	§WALKER, F. SIDNEY - -	Aston, Archer Street, Chatswood Sydney, N.S.W.
1901, Apr. 24	WALLER, WILLIAM THOMAS -	15, Atney Road, Putney, S.W.
1900, Apr. 25	WALMSLEY, WILLIAM HENRY, B.Sc., F.R.A.S.	Nautical Almanac Office, 3, Ver Buildings, Gray's Inn, W.C.
1902, Mar. 26	WALTER, ALBERT, F.R.A.S. -	Royal Alfred Observatory, Mauri
1905, July 6	§§WALTERS, ALFRED - - -	Melbourne Harbour Trust, Melbo Victoria, Australia.
1895, Nov. 27	WARD, HENRY - - -	2, Station Road, West Croydon.
	WARD, ISAAC W. - - -	24, Camden Street, University I Belfast.
1898, Oct. 18	WARD, JOSEPH T. - - -	Victoria Avenue, Wanganui, Zealand.
1901, July 4	§§WARE, SAMUEL, M.A. - -	36, Riversdale Road, Hawthorne, toria, Australia.
1898, Nov. 30	WARNER, WORCESTER R., F.R.A.S. -	Cleveland, Ohio, U.S.A.
1898, Dec. 28	WARRAND, MAJOR-GENERAL J. S., R.E., F.G.S.	Westhorpe Hall, Southwell, Notts.
1893, Dec. 27	WATSON, ALFRED - - -	St. James's School, West Malver
	WATSON, LIEUT.-COL. HARRY JAMES, F.R.A.S.	Deramore, Pine Mount, Camberle
1894, Apr. 25	WATSON, JOHN, F.R.A.S. - -	Halton View, 3, Wilson P Street, Warrington.
1900, Nov. 28	WATT, JAMES - -	St. John's Hill, Wanganui, New land.
	WAUGH, REV. W. R., F.R.A.S. -	The Observatory, Portland, Dors
1898, Nov. 2	WEARING, JOHN, F.R.A.S. - -	Garsdale, Sedbergh, Yorkshire.
1898, Nov. 30	WEEKES, CAPT. - - - -	Willestrew, near Tavistock.
	WEFERS, G. - - - -	3, Clifton Terrace, Coleraine, Irel
	WEINEK, DR. LADISLAUS - -	K. K. Sternwarte, Prague, Bohem
	WEIR, THOMAS, F.R.A.S. - -	56, Parkfield Street, Moss Lane Manchester.
1903, July 21	§WELCH, J. ST. VINCENT - -	Standish, Gore Hill, North Sy N.S.W.
1900, Apr. 25	WELDON, EDWARD, F.R.A.S. - -	Courtlands, Tunbridge Wells.
1899, June 28	WENKER, PROF. HERMANN - -	Meppen, Hanover.
1894, Dec. 19	WESLEY, EDWARD FRANCIS - -	28, Essex Street, Strand, W.C.
	WESLEY, W. H. - - -	Burlington House, Piccadilly, W.
1901, Oct. 30	WESTMORELAND, EDWIN - -	The Gables, Sutton-on-Sea, Li shire.
	WHEELER, AUGUSTUS, *Curator of Lantern Slide Department.*	Park Villa, 44, Stockwell Park S.W.
1898, Jan. 26	WHICHELLO, DR. HAROLD - -	The Mount, Tattenhall, Chester.
1899, Jan. 20	‡WHITE, JOHN - - -	1, Princes Gardens, Dowanhill, Gl
1892, Dec. 28	WHITELOW, EDWARD TURNER, F.R.A.S.	70, Deansgate, Manchester.

Date of Election.		
1897, May 26	§§Whiting, Mrs. Rose - -	Hascombe, Macedon, Victori tralia.
1895, Nov. 27	Whitmell, Charles Thomas, M.A., B.Sc., F.R.A.S., H.M.I.S.	Invermay, Hyde Park, Leeds.
1902, Feb. 26	Whitmell, Mrs. - - -	Invermay, Hyde Park, Leeds.
1901, Feb. 27	Whittaker, Edmund Taylor, M.A., F.R.A.S.	Trinity College, Cambridge.
1897, Apr. 28	Whyte, Rev. Charles - .	F. C. Manse, Dunrossness, She
1902, Mar. 26	Wickham, R. - - -	Victoria Road, Kington, H shire.
1899, Mar. 29	Wicks, Mark - - -	Norman Villa, 19, Liverpool Thornton Heath, Croydon.
1894, May 30	Wigglesworth, Robert, F.R.A.S. -	Great Chapel Street, Westminst
1896, Nov. 25	Wigram, Miss Harriet - -	Northleys, Much Haddam, He
1905, Apr. 26	Wilbraham, Miss Sybil - .	Cresswellshawe, Alsager, Ches
	Wilding, Richard, F.R.A.S., Director of Photographic Section.	Dalwhinnie, Bromley, Kent.
1895, Dec. 18	*Wildy, Augustus George - -	1, Raymond Buildings, Gra W.C.
	Wilkins, Thomas S. - -	Uttoxeter.
1896, Oct. 28	Willett, Rev. Wilmer Mackett, M.A.	Helmaen, near Usk, Mon.
	Williams, Arthur Stanley, F.R.A.S.	Bella Vista, 20, Hove Park Vill Brighton.
1893, Nov. 29	Williams, Rev. Leonard A. -	Stoke Wake Rectory, Blandfo
1904, May 5	§§Williams, William Henry -	Walker's Coffee Palace, We bourne, Australia.
1895, Feb. 27	Willis, Edgar Colman . -	Southwell Lodge, Ipswich Norwich.
1891, Nov. 25	Willmott, Miss E. A. - -	Warley Place, Great Warley, I
1892, June 21	Wilson, James - - -	Helstonleigh, Gill Street, Most Manchester.
1897, Jan. 27	Wilson, Robert D. - - -	38, Upper Brook Street, W.
	*Wilson, William E., F.R.S., F.R.A.S.	Daramona, Streete, co. We Ireland.
1902, Dec. 31	Wood, E. J. - - - -	The Clifton Pharmacy, York.
1902, May 20	§Woodhouse, Prof. W. J., M.A. -	The University, Sydney, N.S.V
1900, June 27	Woolston, Miss Mary Elizabeth	High Street, Wellingborough.
1895, Oct. 30	Worrall, George - - -	Spring Bank, West Newport, I
1904, Jan. 27	Worringham, T. P. G. - -	15, Longfellow Street, East Cape Colony.
1897, Nov. 24	Worssell, W. M. - - -	Box 14, Johannesburg. Tr South Africa.
1891, Mar. 25	Wright, Frederick - -	21, Elsie Road, East Dulwich,
1894, Nov. 28	§Wright, Hugh - - -	Public Library, Sydney, N.S.W
1897, Oct. 27	Wright, James - - -	36, Douglas Street, Kirkcaldy,
	Wright, T. - - -	33, Nigel Road, Peckham Ry
1899, Dec. 27	Wyles, Henry, L.D.S. - -	24, Blenheim Terrace, Leeds.
1892, Nov. 30	Wyndham, Henry - - -	Thornton Lodge, Thornton Surrey.

Date of Election.		
1893, Jan. 10	Young, Arthur - - -	Ashwood, The Drive, Sevenoaks, Ke
	Zenger, Prof. Charles Venceslas, F.R.A.S.	7, Landtagsgasse, Prague, I Bohemia.

The following is a list of Members whose deaths occurred subsequently to the payment
heir subscriptions for the 1904–05 Session, and who must, therefore, be counted as members
he financial statement relating to that Session :—

Bompas, George C.
Freeman, Augustus.

EXCHANGES AND PRESENTATIONS.

The Royal Society.
The Royal Astronomical Society.
The Royal Institution.
The Smithsonian Institution, Washington.
The American Philosophical Society.
Académie des Sciences, Paris.
Société astronomique de France.
Società degli Spettroscopisti Italiani.
Comité international de la Carte photographique du Ciel.
The Astronomical Society of the Pacific.
The Toronto Astronomical Society.
The Astronomical Society of Wales.
Société Belge d'Astronomie.
The Royal Observatory, Greenwich.
The Royal Observatory, Edinburgh.
The University Observatory, Oxford.
The Radcliffe Observatory, Oxford.
The Royal Observatory, Cape of Good Hope.
The National Observatory, Paris.
The Royal Observatory, Belgium.
The United States Naval Observatory, Washington.
The Lick Observatory, Mount Hamilton, Cal., U.S.A.
Harvard College Observatory, Cambridge, U.S.A.
The Allegheny Observatory, Allegheny, Pa., U.S.A.
The Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.
The Washburn Observatory, Madison, Wisconsin, U.S.A.
The Lowell Observatory, Ariz., U.S.A.
The University of Upsala.
The South Kensington Museum Library.
University College Library, London.
The Patent Office Library, London.
"The Observatory," London.
"Bulletin astronomique," Paris.
"Astronomische Nachrichten," Kiel.
"Ciel et Terre," Brussels.
"Himmel und Erde," Berlin.
"The Astrophysical Journal."
"Popular Astronomy," Northfield, Minn., U.S.A.
"The Astronomical Journal," Cambridge, Mass., U.S.A.
"Knowledge," London.